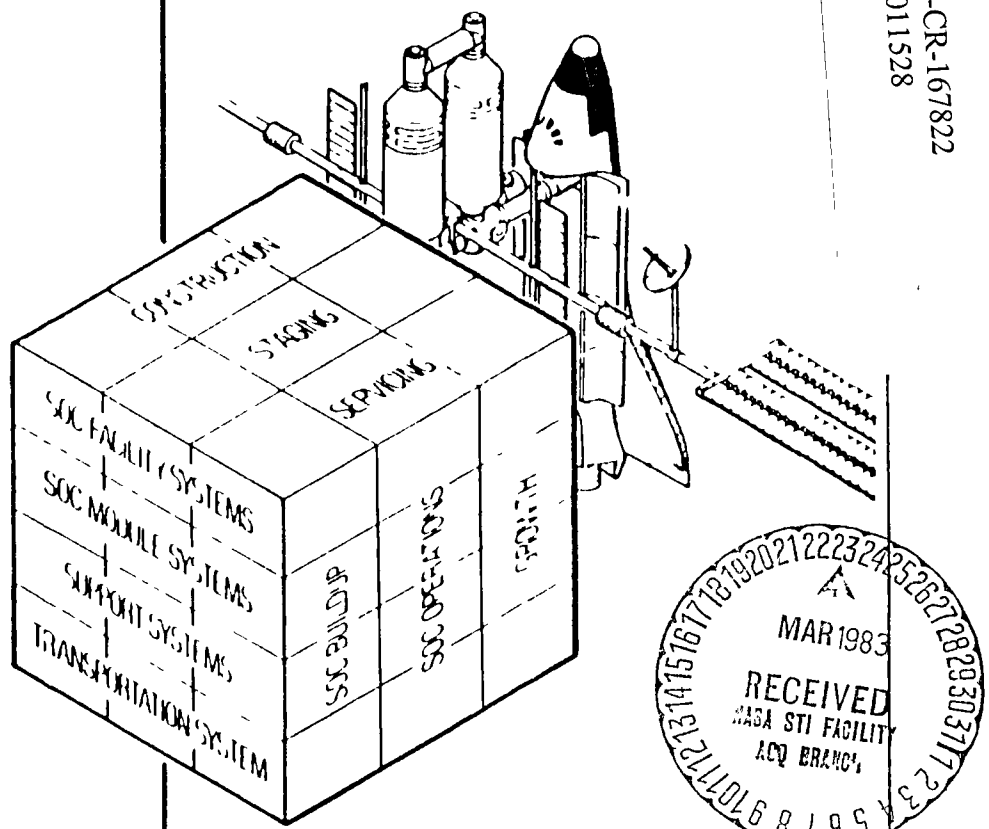
PD81-7

SPACE OPERATIONS CENTER

SHUTTLE INTERACTION STUDY

FINAL REVIEW



NAS9-16153

Space Operations and
Satellite Systems Division

Rockwell International

1 APR 1981

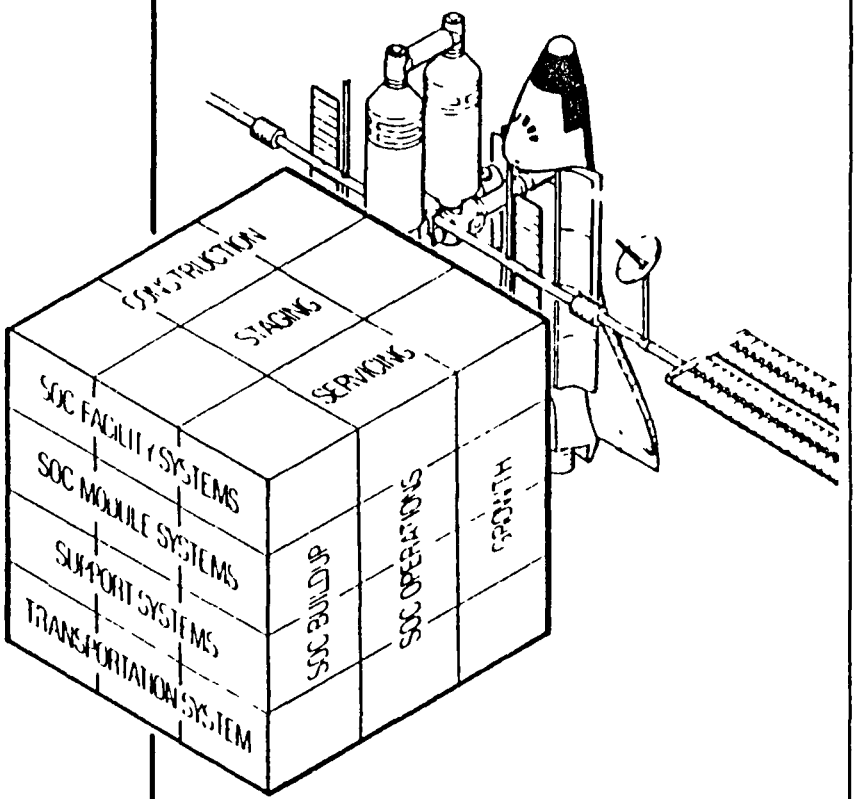
PD81-7

SPACE OPERATIONS CENTER

SHUTTLE INTERACTION STUDY

FINAL REVIEW

NAS9-16153

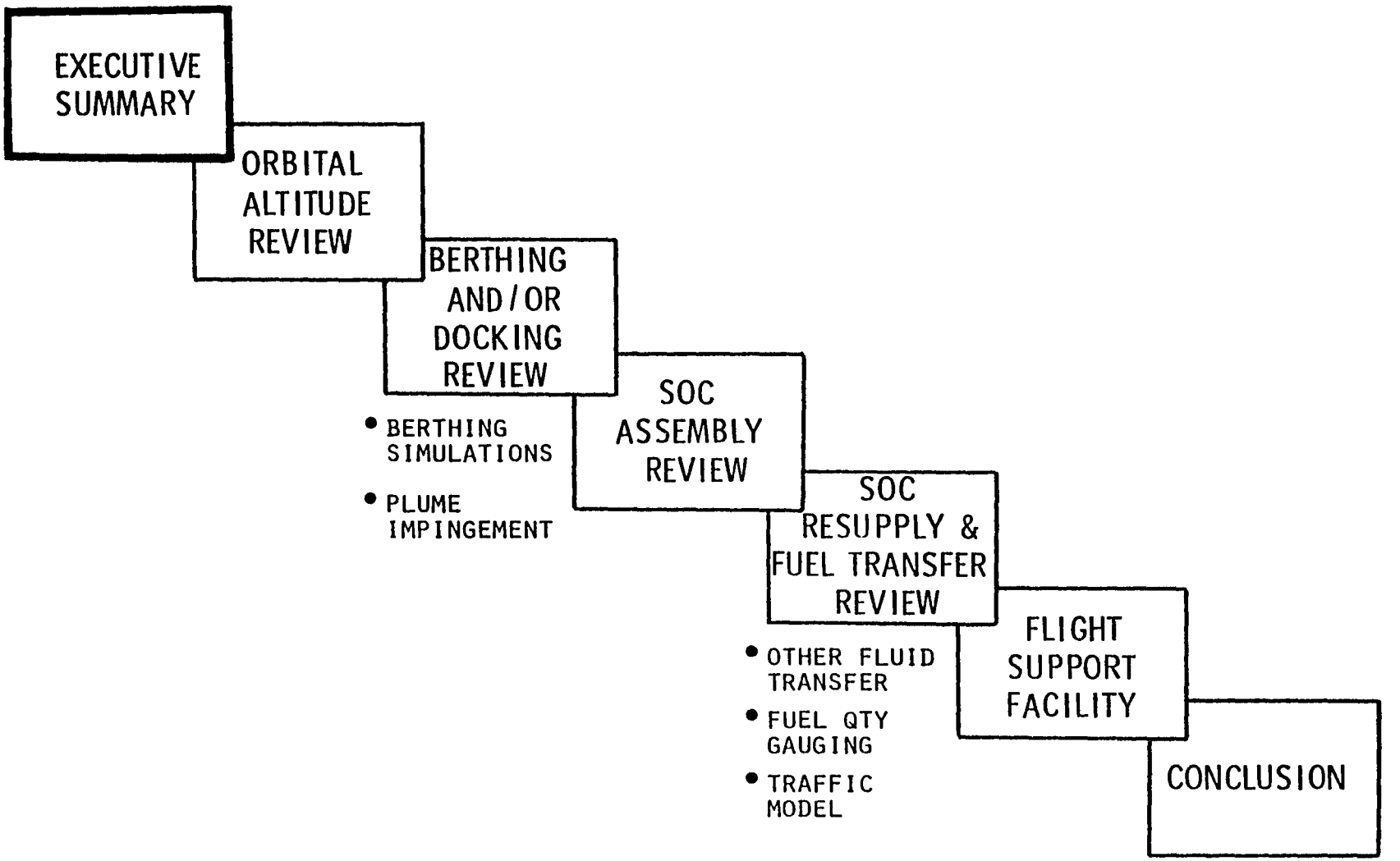


Space Operations and Satellite Systems Division

Rockwell International

1 APR 1981

AGENDA


EXECUTIVE SUMMARY
ORBITAL ALTITUDE REVIEW
BERTHING AND/OR DOCKING REVIEW
• BERTHING SIMULATIONS
• PLUME IMPINGEMENT
SOC ASSEMBLY REVIEW
SOC RESUPPLY & FUEL TRANSFER REVIEW
• OTHER FLUID TRANSFER
• FUEL QTY GAUGING
• TRAFFIC MODEL
FLIGHT SUPPORT FACILITY
CONCLUSION

EXECUTIVE SUMMARY

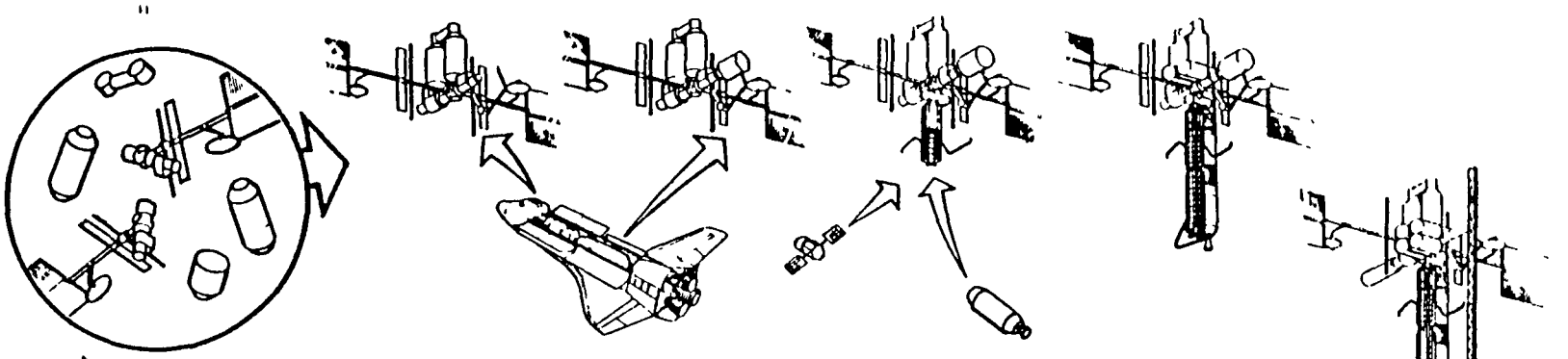
EXECUTIVE SUMMARY CONTENT

STUDY OBJECTIVE

"ANALYZE, IN A PRELIMINARY FASHION, THE IMPLICATION OF USING THE SHUTTLE WITH THE SOC, INCLUDING CONSTRAINTS THAT THE SHUTTLE WILL PLACE UPON THE SOC DESIGN. IDENTIFY ALL THE CONSIDERATIONS INVOLVED IN THE USE OF THE SHUTTLE AS A PART OF THE SOC CONCEPT."

- IMPLICATIONS TO THE SOC
- IMPLICATIONS TO THE SHUTTLE
- IMPLICATIONS TO AN OTV/MOTV

SOC GROWTH CONCEPT



SPACE OPERATIONS CENTER ELEMENTS

SOC | SHUTTLE | SPACECRAFT

MISSION PHASES

BUILD-UP/ ASSEMBLY → EARLY OPERATIONAL STATUS → MISSION GROWTH

MISSION GROWTH → MULTIPLE OPERATIONS → SATELLITE/ SPACECRAFT SERVICING → CONSTRUCTION

MULTIPLE OPERATIONS → MULTIPLE SHUTTLE | GEO SORTIE | PROPELLANT SERVICE STATION

MULTIPLE SHUTTLE → STAGING EXPENDABLE | STAGING RETURN

SATELLITE/ SPACECRAFT SERVICING → R&D PROJECTS | MULTIPLE SHUTTLE PROJECTS

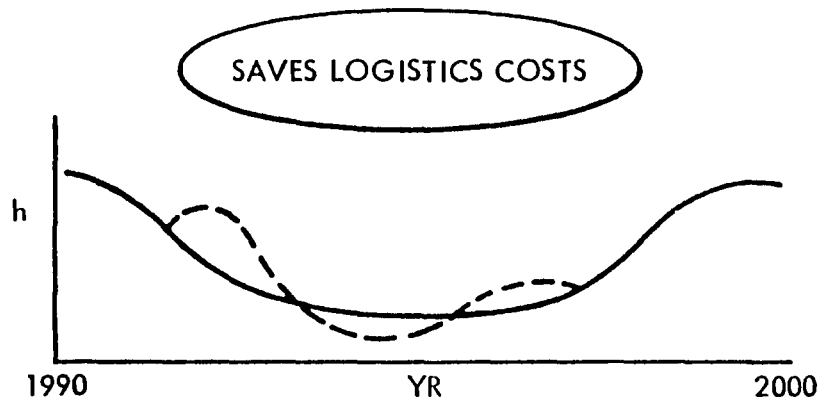
IMPLICATIONS TO THE SPACE OPERATIONS CENTER (SOC)

SOC ORBIT ALTITUDE IMPLICATIONS

USE VARIABLE ALTITUDE STRATEGY

FLY HIGH ALT
- LO TRAFFIC
- HI ATMOS DENSITY

FLY LOW ALT
- HI TRAFFIC
- LOW ATMOS DENSITY

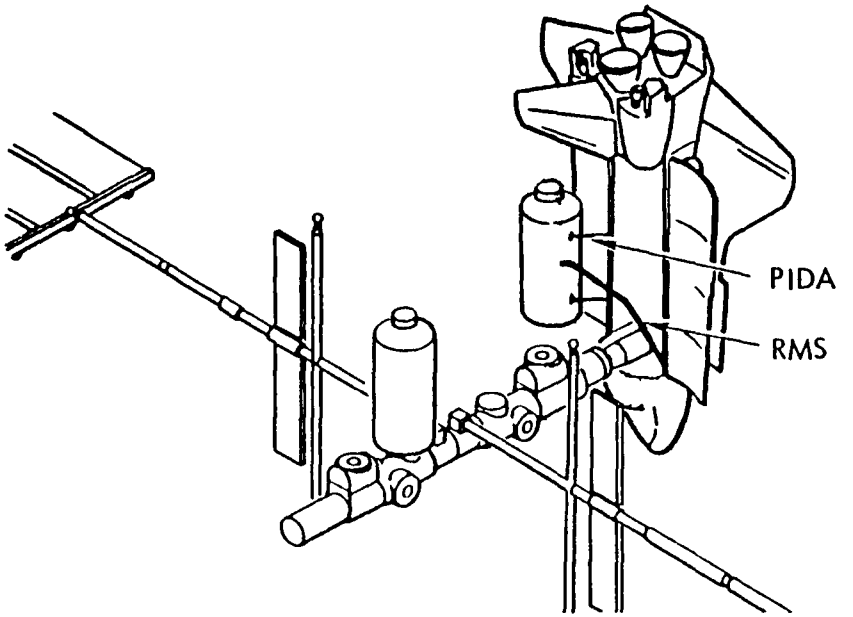


IMPLICATIONS

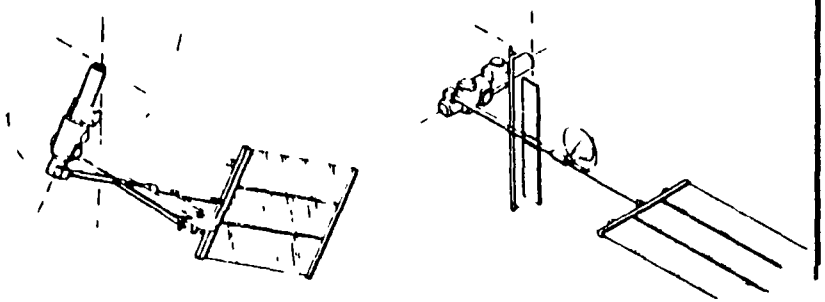
- SIZES PROPELLANT CAPACITY ON SOC
- UNIQUE OPERATIONAL ACTIVITIES REQUIRED TO COORDINATE LOGISTICS DELIVERY SCHEDULES & MANIFESTS WITH SOC ALTITUDE
- COMM/DATA LINK FOR SOLAR ACTIVITY DATA REQUIRED

SOC ASSEMBLY IMPLICATIONS

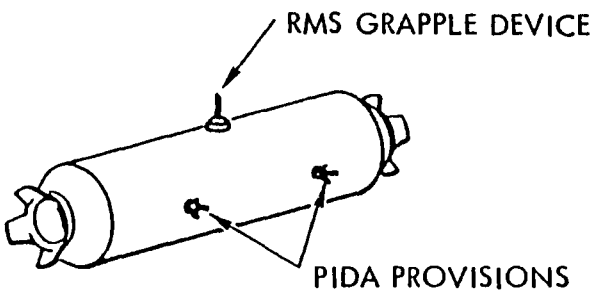
MODULE DEPLOYMENT & TRANSPORT



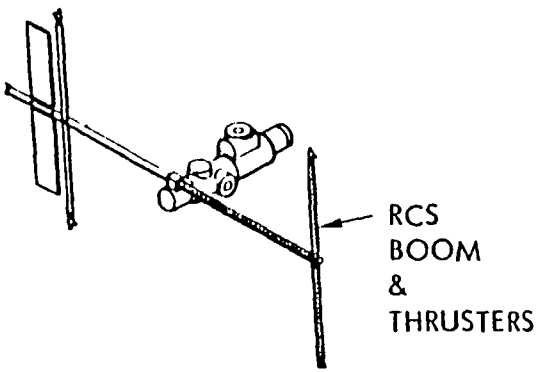
UNTENDED OPERATIONS



IMPLICATIONS



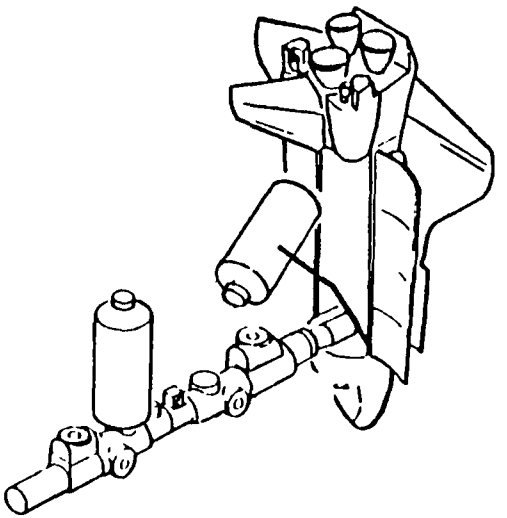
- PIDA INTERFACE PROVISIONS
- RMS GRAPPLE DEVICE INSTALLATION



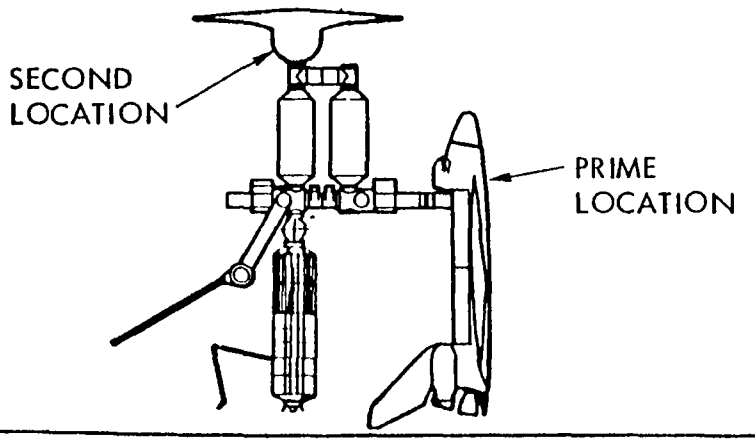
- RCS BOOM & THRUSTERS REQUIRED FOR ADEQUATE CONTROL COUPLES

SOC ASSEMBLY IMPLICATIONS

ASSEMBLY ALIGNMENT

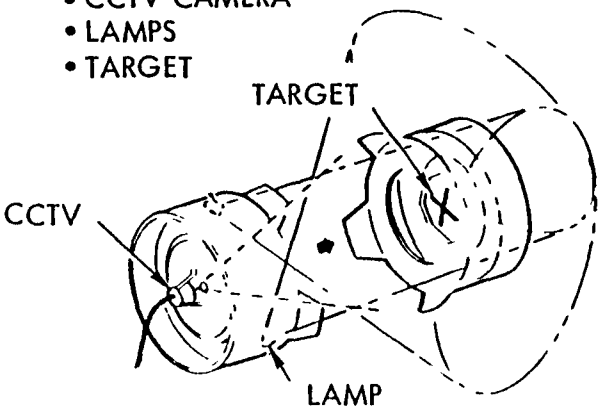


ORBITER DOCKING LOCATIONS

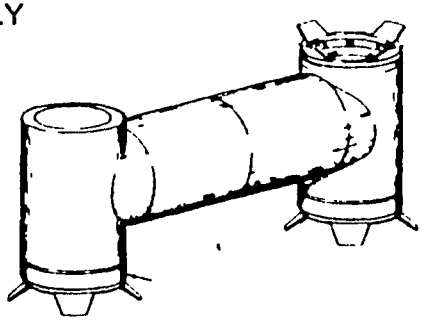


IMPLICATIONS

- ALIGNMENT KIT REQUIRED FOR MODULE ASSEMBLY
  - MOUNTING PROVISIONS FOR
    - CCTV CAMERA
    - LAMPS
    - TARGET



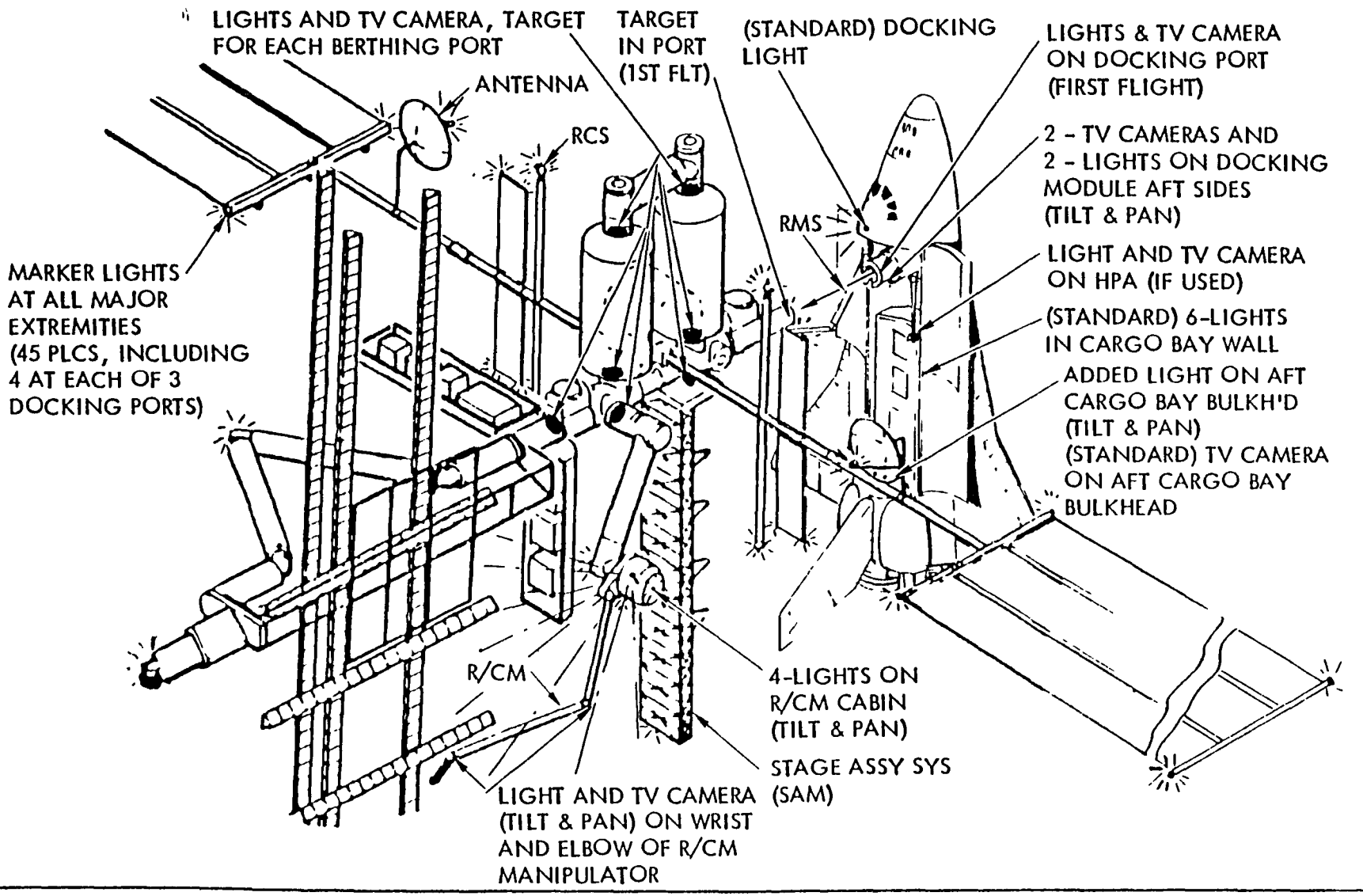
- INTERFACE PORT REQUIRED ON TUNNEL ASSEMBLY



- PORT ORIENTED FOR TAIL DOWN ORBITER POSITION

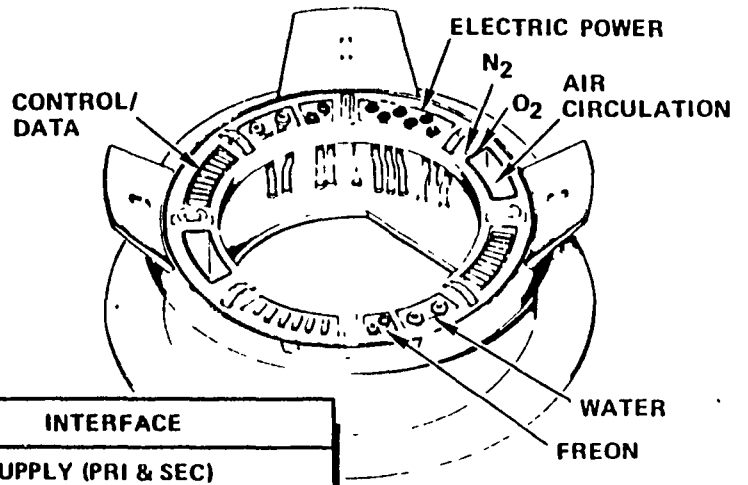
SOC ASSEMBLY IMPLICATIONS

LIGHTS & TV CAMERAS FOR SOC ASSEMBLY & SOC OPERATIONS



DOCKING AND/OR BERTHING IMPLICATIONS

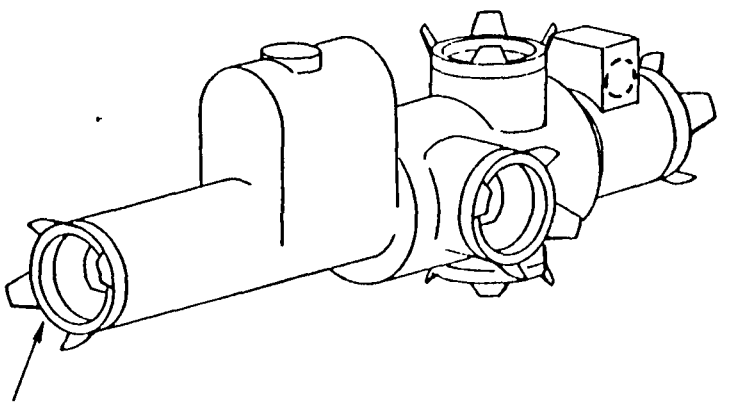
STANDARD MATING INTERFACE



INTERFACE
FREON SUPPLY (PRI & SEC)
FREON RETURN (PRI & SEC)
H_2O COOLANT SUPPLY (PRI & SEC)
H_2O COOLANT RETURN (PRI & SEC)
H_2O COOLANT RETURN (PRI & SEC)
H_2O POTABLE SUPPLY
H_2O WASTE RETURN
O_2 SUPPLY
N_2 SUPPLY
AIR PRESSURE
AIR PROCESSING DUCTS
ELEC. POWER-PRIMARY
ELEC. POWER-SECONDARY
DATA/CONTROL
G/N-RCS
ECLSS
ISS
COMM -AUDIO/VISUAL
DATA-DIGITAL/ANALOG

IMPLICATIONS

- ALL SOC MODULES TO INCORPORATE THE PASSIVE STANDARD INTERFACE PORT

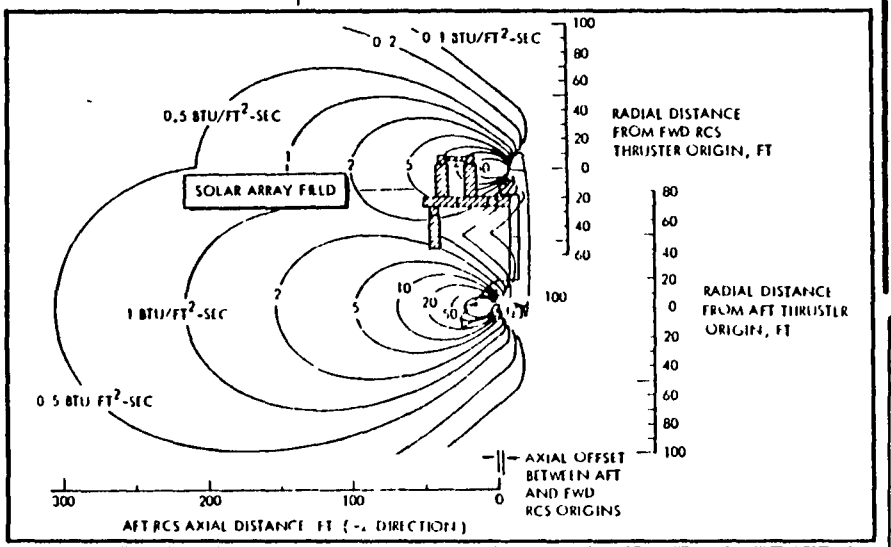


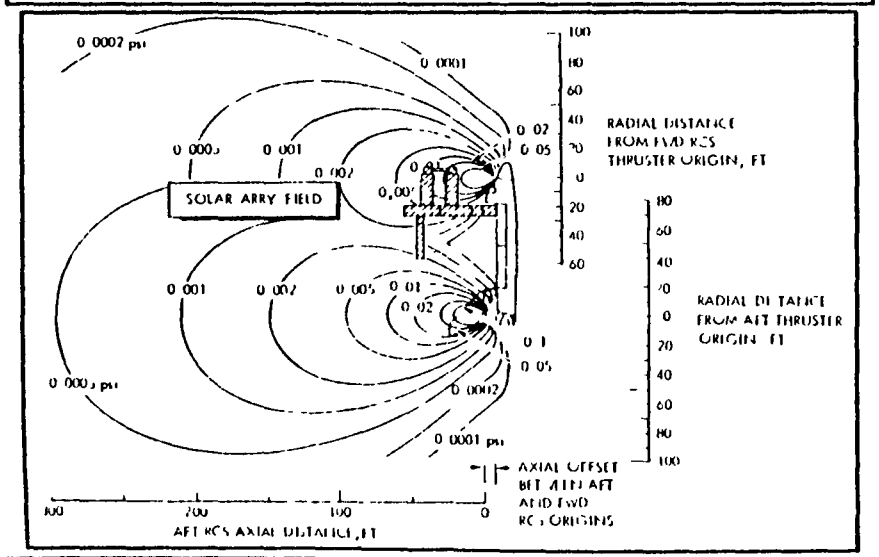
- STANDARD MATING INTERFACES
- PASSIVE PORTS

DOCKING AND/OR BERTHING IMPLICATIONS

RUNAWAY JET CONDITION

- ABORT MODE PLUME IMPINGEMENT





IMPLICATIONS

- SOC DESIGN TO INCORPORATE RUNAWAY JET ABORT Hi-Z THRUST IMPACTS, PRESSURE, TEMPERATURE & CONTAMINANTS
- UNPROTECTED INSULATION (MLI) SUBJECT TO DAMAGE FROM ABORT THRUST PRESSURES

DESCRIPTION	MASS* DEPOSITION RATE (lbm/sec)	SOC IMPINGEMENT FORCES (lbf)			SOC MOMENTS (lbf ft)			CONVECTIVE HEATING RATE (BTU/sec)
		F_x	F_y	F_z	M_x	M_y	M_z	
FWD RCS 3 ENGINES (-Z DIRECTION)								
HABITABILITY MODULE NO 1	3.146	981.1	0	41.8	0	24 058.1	0	7730.0
LOGISTICS MODULE	0.272	59.7	11.7	60.6	805.0	508.2	695.0	637.7
SERVICE MODULE NO 1	0.266	41.2	0	39.0	0	789.4	0	609.9
TOTAL	3.684	1082.0	11.7	47.8	805.0	23 260.5	695.0	
AFT RCS 6 ENGINES (-Y DIRECTION)								
PARKED PLANETARY VEHICLE	0.334	90.6	1	50.8	0	5 185.2	0	773.2
SAW**	2.564	867.2	0	70.2	0	67 579.0	0	6560.6
R/CM MODULE	0.280	60.0	23.5	19.2	1258.2	2 252.9	747.2	549.8
TOTAL	1.198	1017.8	23.5	19.8	1258.2	76 020.5	747.9	
+Y THRUSTER, 1 ENGINE								
SOLAR ARRAY (@ 52° ANGLE)	0.720	116.2	171.4	65.1	6018.6	1951.3	19 550.1	1659.8
S-1 N ANTENNA (-Y DIRECTION)	0.036	1.2	5.6	0.6	121.2	55.2	220.6	45.9
RADIATORS (-Y DIRECTION)	0.009	2.1	1.4	0.5	15.1	20.3	79.0	20.6
TOTAL	0.765	122.2	178	66.0	6176.2	1881.8	19 853.8	

*NOTES (1) ONE ENGINE PRODUCES 870 lbf THRUST
(2) MASS FLOW RATE OF ONE ENGINE = 3.01 lbm/sec
(3) MASS FLOW CONTAINS APPROX 98 CO, 17 SE CO and 29 31 H 0

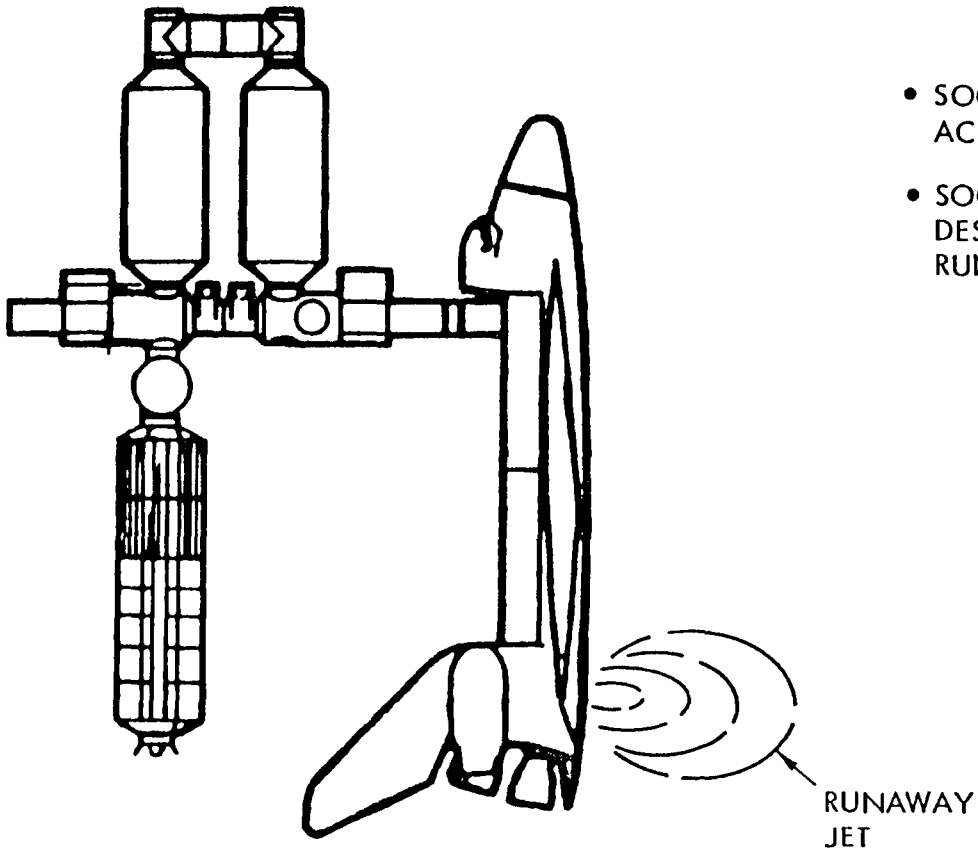
**ASSUMED THAT THE SAW WAS OPAQUE (INTERNAL PARTS STOWAGE)

FORCE, MOMENT, HEATING SUMMARY

DOCKING AND/OR BERTHING IMPLICATIONS

RUNAWAY JET CONDITION

- CONTACT MODE

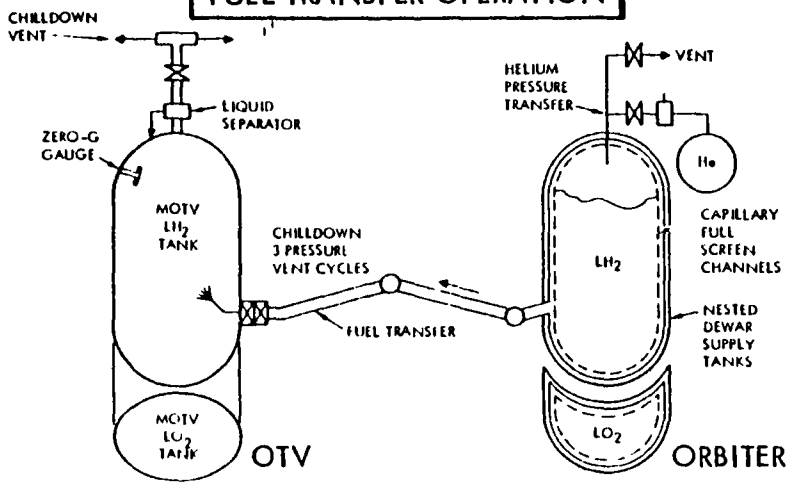


IMPLICATIONS

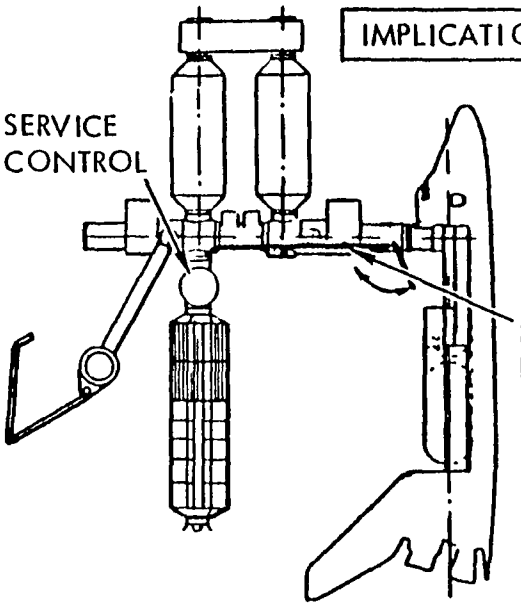
- SOC/ORBITER INTERFACE DESIGNED TO ACCEPT RUNAWAY JET LOADS AFTER MATING
- SOC ATTITUDE CONTROL MUST BE DESIGNED TO ACCOMMODATE THE RUN AWAY JET IMPOSED FORCES

FUEL TRANSFER IMPLICATIONS

FUEL TRANSFER OPERATION



IMPLICATIONS

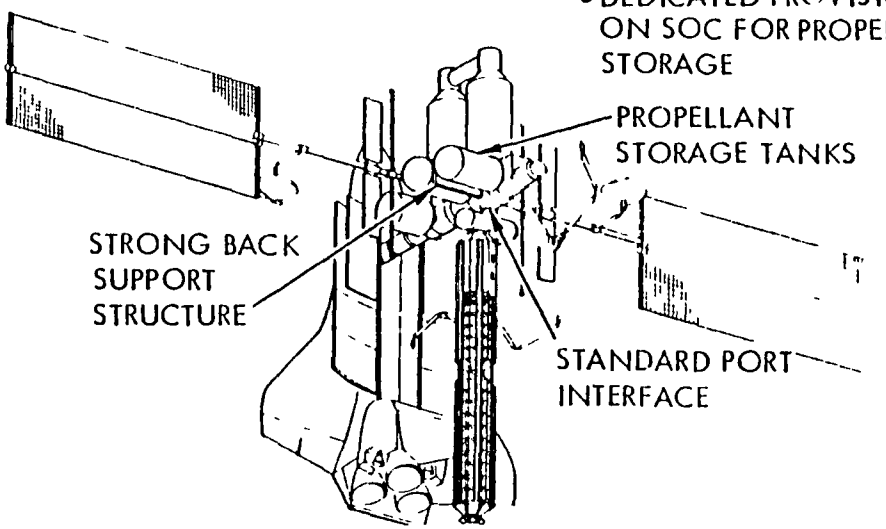


- FUEL TRANSFER CONTROL FROM SOC
- TRANSFER LINE(S) ON SOC

PROPELLANT STORAGE BENEFITS

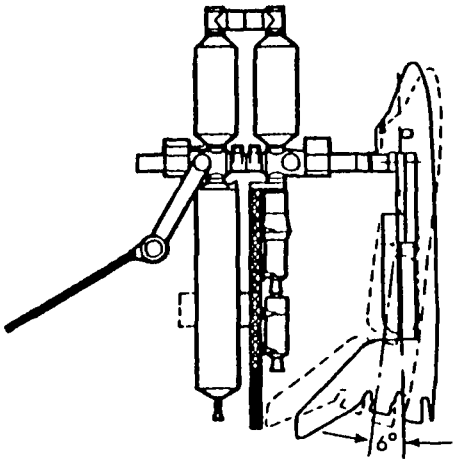
- PROPELLANT LOGISTICS SAVINGS
  - ET PROPELLANT RECOVERY
  - ELIMINATE ROUND-OFF FLTS
  - REFRIGERATION
- UNCOUPLE LOGISTICS
  - EASE FLEET PLANNING
  - IMPROVE SHUTTLE UTILIZATION
- RAPID MISSION RESPONSE
  - HI-VALUE SERVICES
  - RESCUE

- DEDICATED PROVISIONS ON SOC FOR PROPELLANT STORAGE

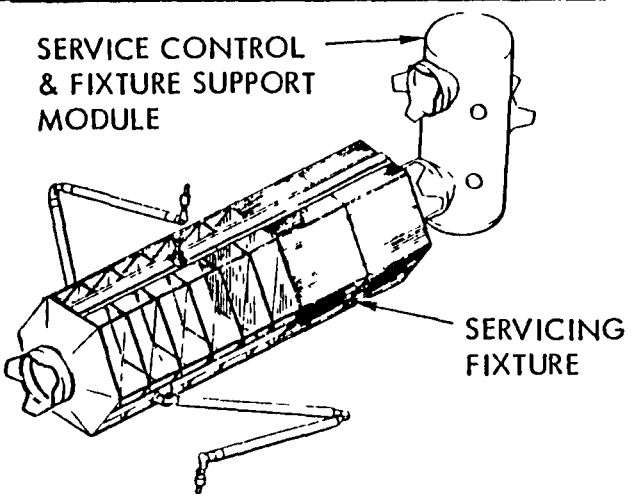


FLIGHT SUPPORT FACILITY IMPLICATIONS

ORBITER DOCKING MISALIGNMENT

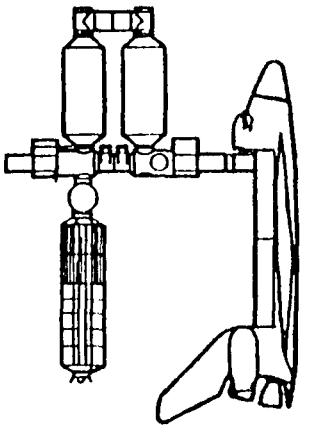


SERVICING FACILITY ASSEMBLY

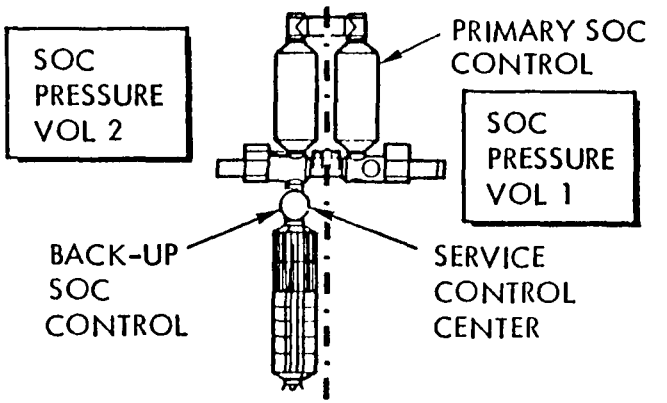


IMPLICATIONS

- FLIGHT SUPPORT FACILITY RELOCATED FOR CLEARANCE

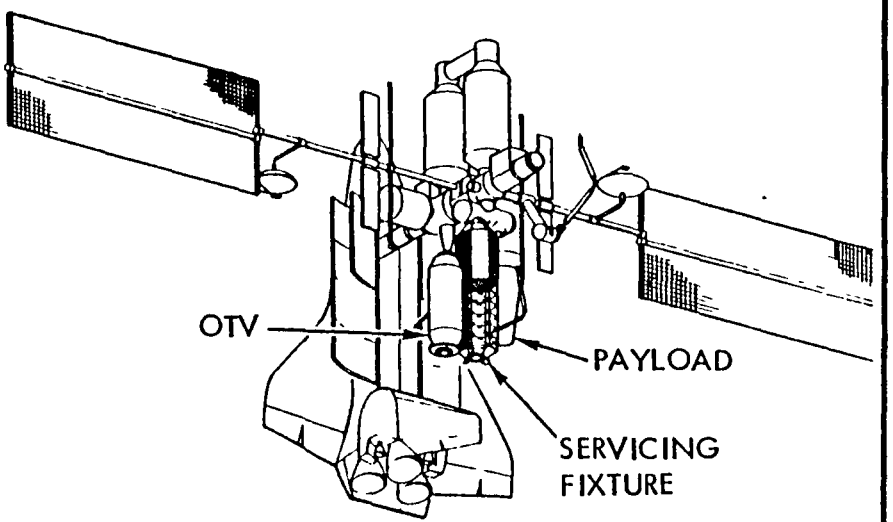


- SOC PRIMARY CONTROL CENTER LOCATED IN SOC PRESSURE VOL 1



SOC FLIGHT SUPPORT FACILITY CONCEPT

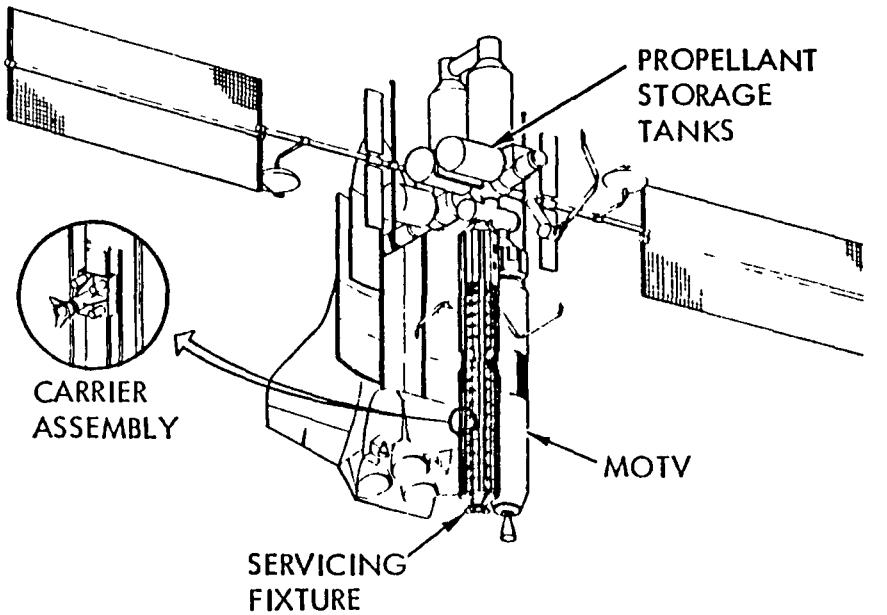
INITIAL ARRANGEMENT



CAPABILITIES:

- ASSEMBLY, LAUNCH, RETRIEVE EARLY GEO SATELLITE DELIVERY MISSIONS
- SERVICE SINGLE STAGE OTV
- REFUEL FROM ORBITER

GROWTH ARRANGEMENT



CAPABILITIES:

- ASSEMBLE, LAUNCH, RETRIEVE MOTV MISSIONS
- SERVICE 2 STAGE MOTV, AND OTHER SPACECRAFT SIMULTANEOUSLY
- PROPELLANT STORAGE ON SPACE BASE

SOC IMPLICATIONS

OPERATIONAL

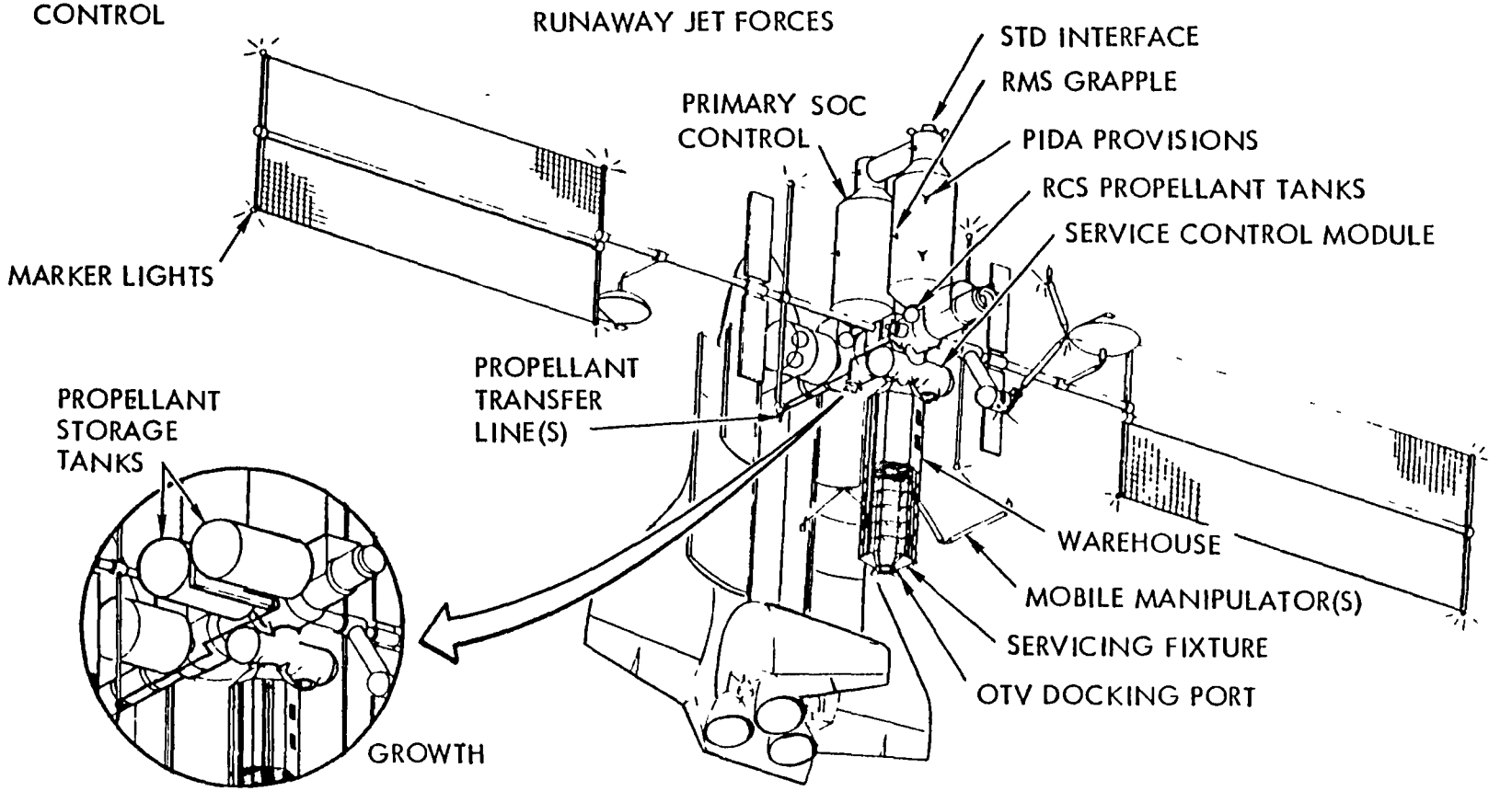
- COORDINATE OPERATIONAL ALTITUDE WITH LOGISTICS TRAFFIC DENSITY
- PROPELLANT TRANSFER CONTROL

DESIGN CRITERIA

- RUN-AWAY JET ABORT PLUME PRESSURES, HEATING & CONTAMINANTS
- SOC ATTITUDE CONTROL RUNAWAY JET FORCES

TEMPORARY ASSEMBLY REQUIREMENTS

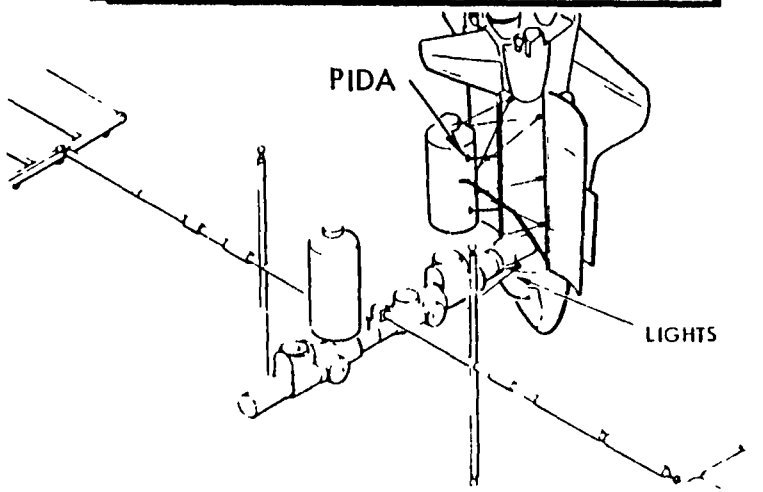
- RCS BOOM & THRUSTERS
- MODULE ALIGNMENT KIT



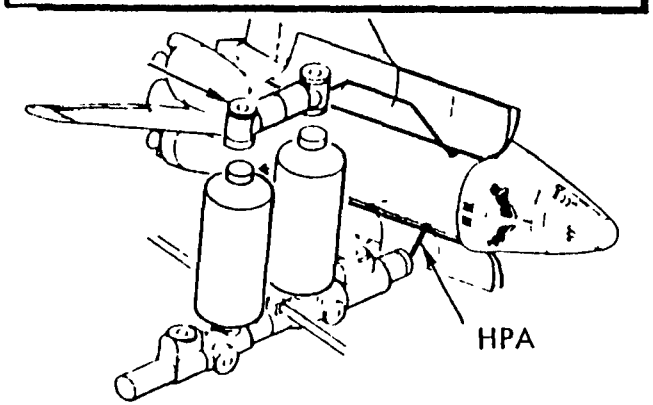
IMPLICATIONS TO THE SHUTTLE

SHUTTLE SOC ASSEMBLY IMPLICATIONS

SOC MODULE DEPLOYMENT FROM ORBITER PAYLOAD BAY

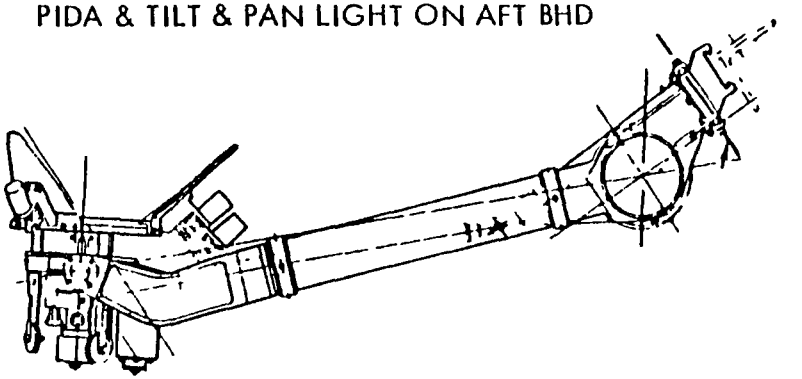


SOC SUPPORTED FOR RMS REACH CAPABILITY

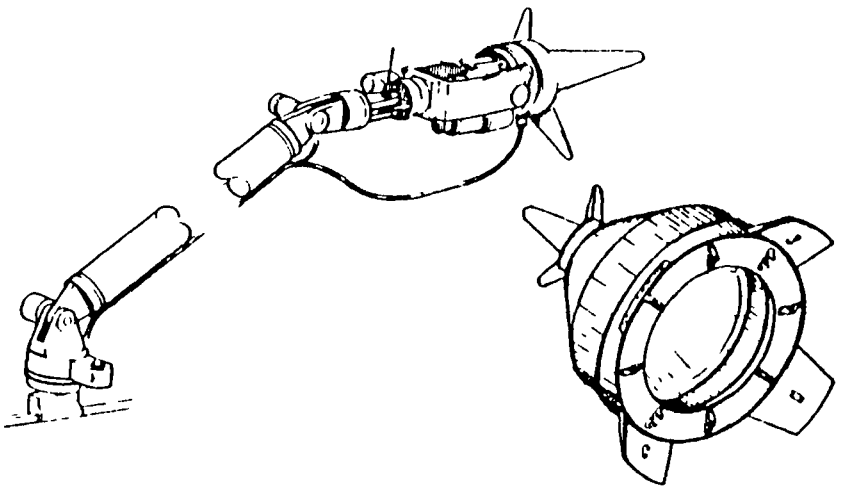


IMPLICATIONS

- PROVIDE INSTALLATION & CONTROLS FOR PIDA & TILT & PAN LIGHT ON AFT BHD

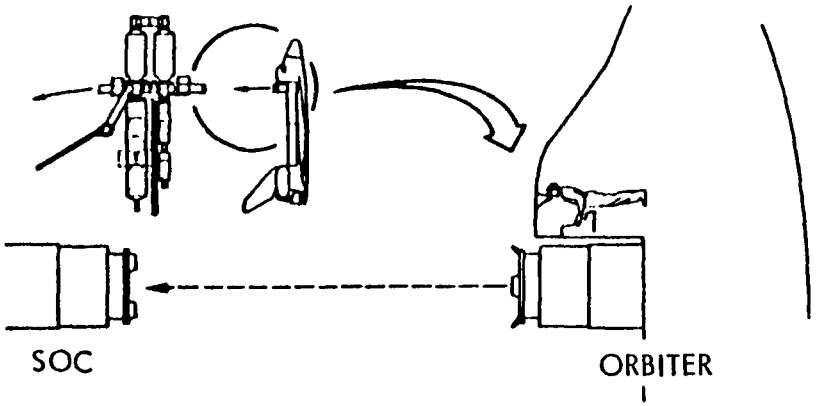


- PROVIDE INSTALLATION OF HPA
- PROVIDE ADAPTER

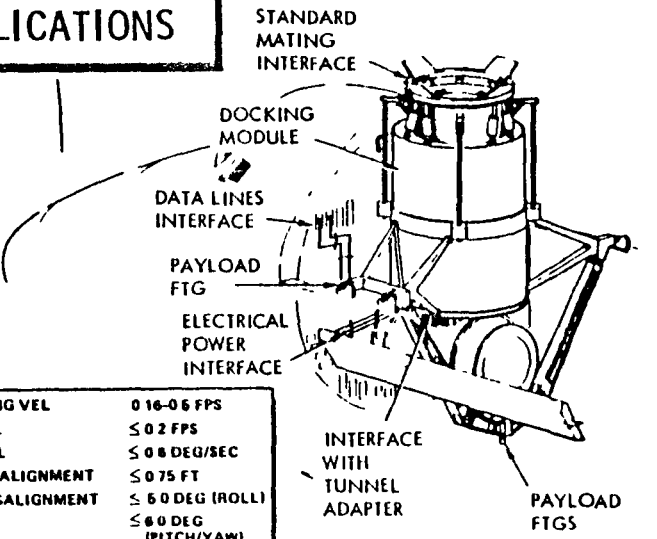


SHUTTLE BERTHING AND/OR DOCKING IMPLICATIONS

DOCKING OPERATIONS

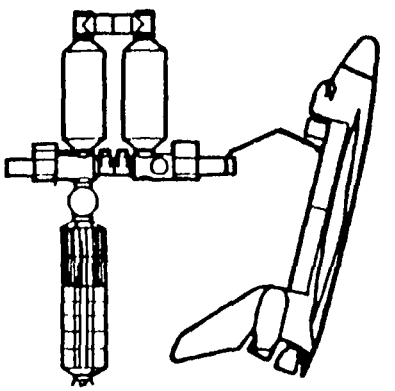


IMPLICATIONS



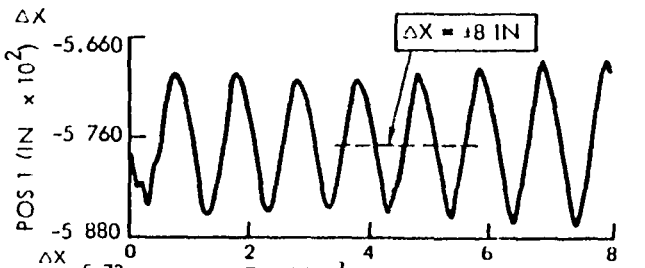
AXIAL CLOSING VEL	0 16-0 6 FPS
LATERAL VEL	≤ 0 2 FPS
ANGULAR VEL	≤ 0 8 DEG/SEC
LATERAL MISALIGNMENT	≤ 0 75 FT
ANGULAR MISALIGNMENT	≤ 6 0 DEG (ROLL)
	≤ 6 0 DEG (PITCH/YAW)

BERTHING OPERATIONS

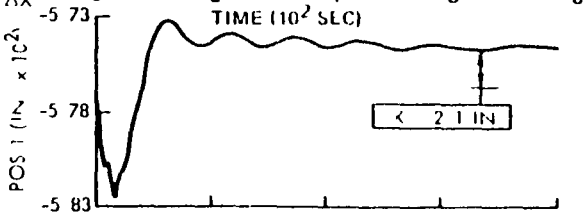


- RMS SOFTWARE MODIFICATIONS REQD FOR BERTHING ORBITER TO SOC

RUN 1, ΔX



RUN 3, ΔX

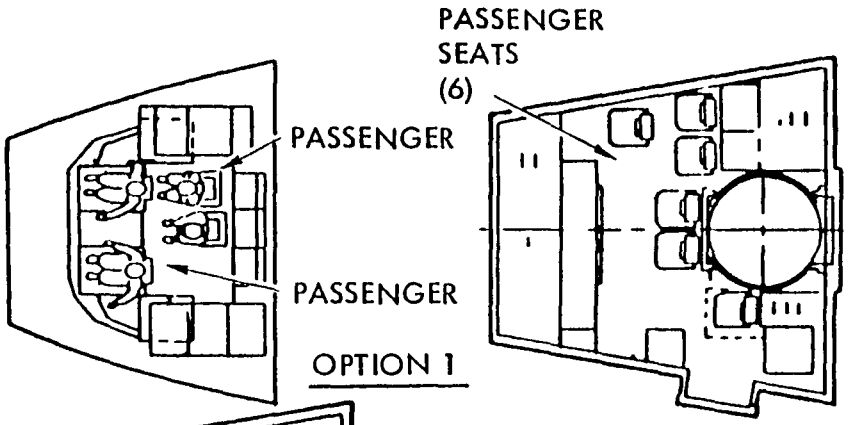


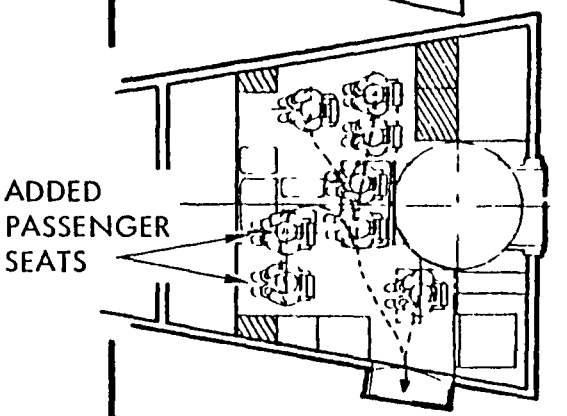
SHUTTLE CREW TRANSPORT IMPLICATIONS

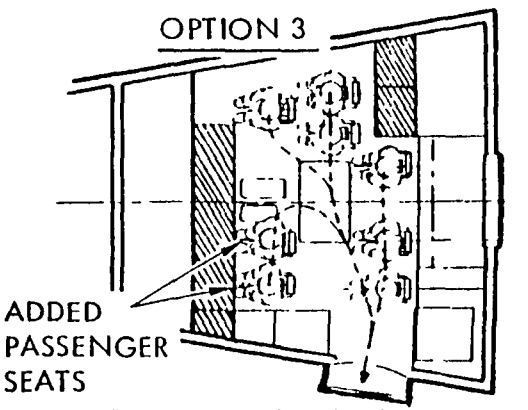
TRANSPORT TO OR FROM THE SOC A FULL CREW OF EIGHT PERSONS

IMPLICATIONS

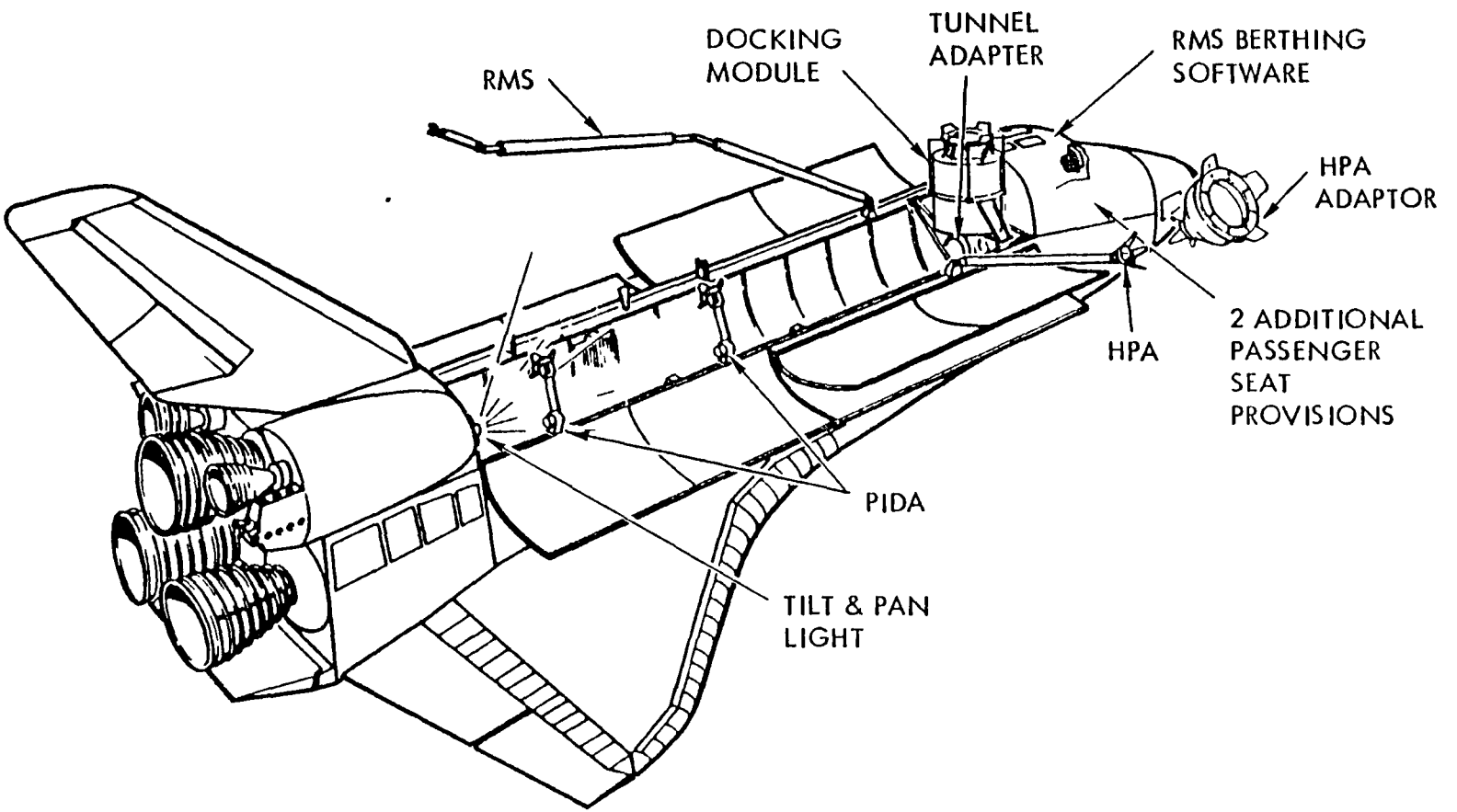
- THREE OPTIONS AVAILABLE. TWO REQUIRE PROVISIONS FOR TWO ADDITIONAL SEATS IN ORBITER MID-DECK







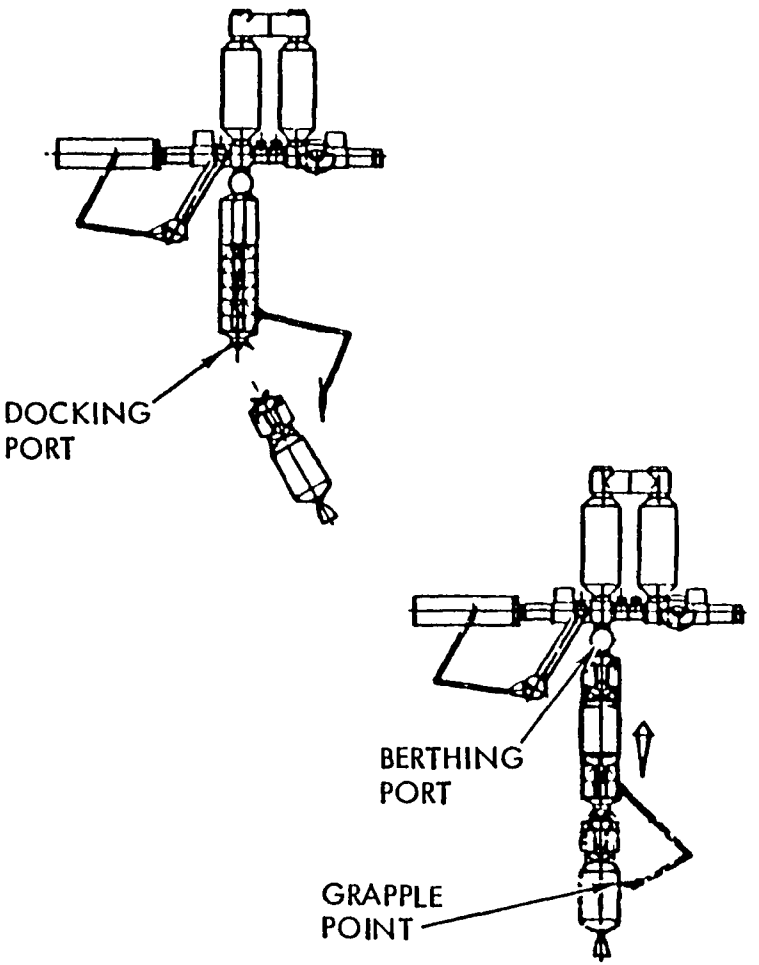
SHUTTLE IMPLICATIONS



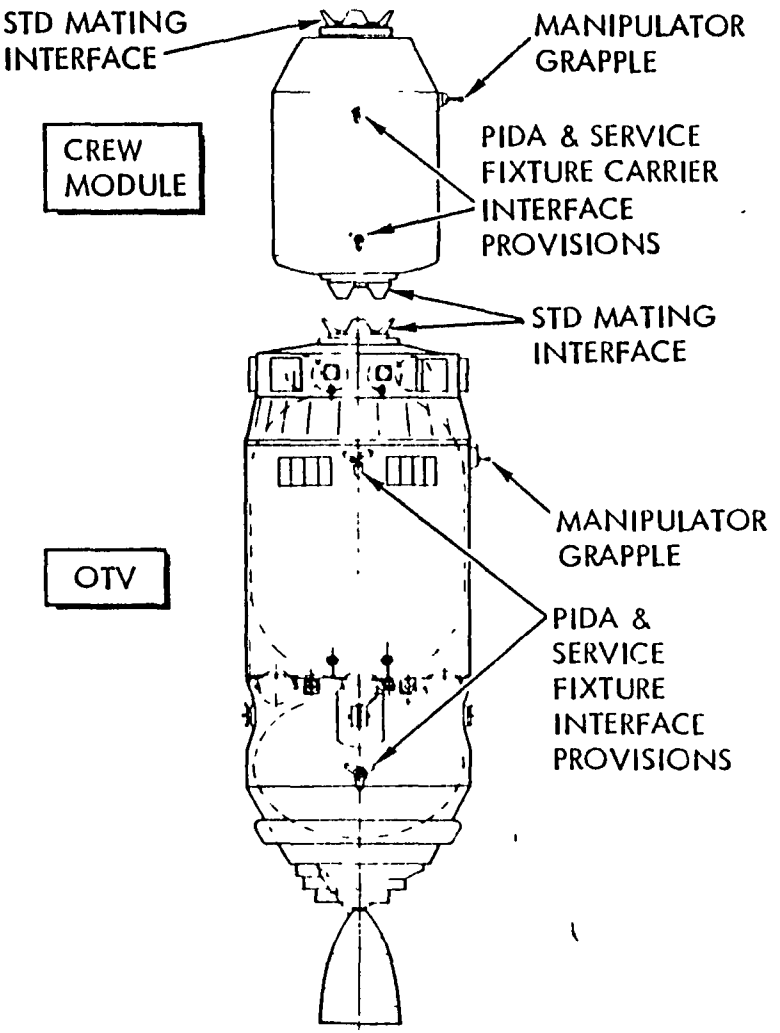
IMPLICATIONS TO AN OTV/MOTV

OTV DOCKING/BERTHING IMPLICATIONS

OTV/MOTV DOCK TO SERVICE FIXTURE & SERVICE CONTROL MODULE

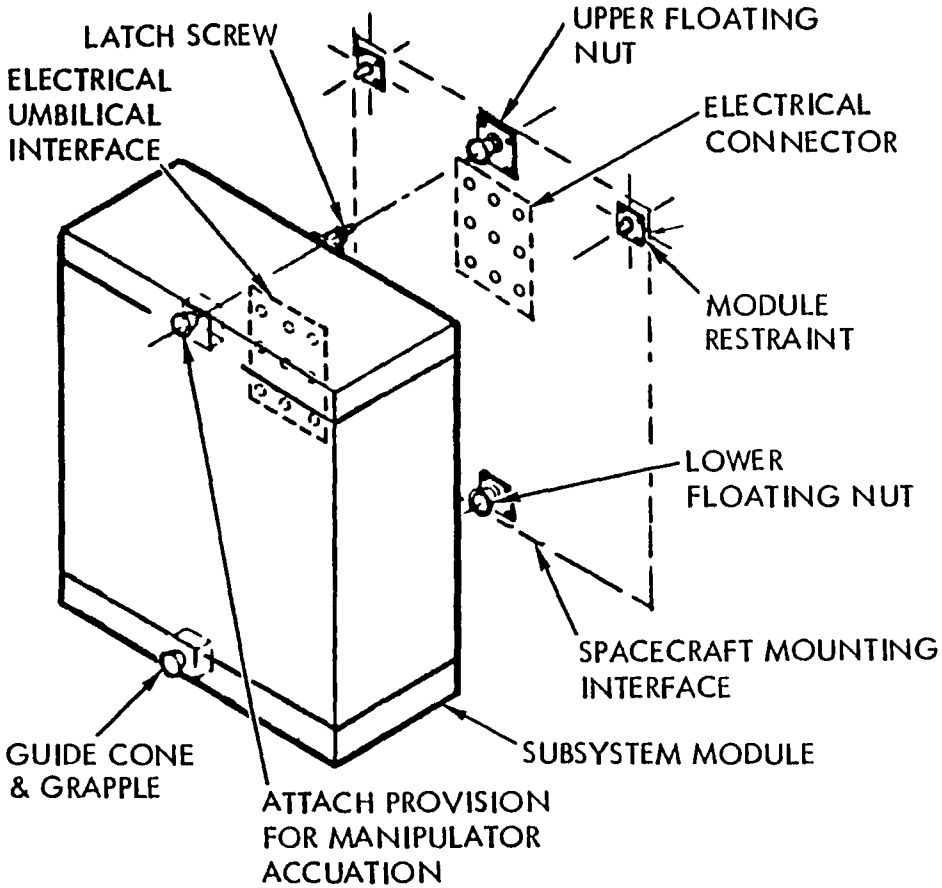


IMPLICATIONS



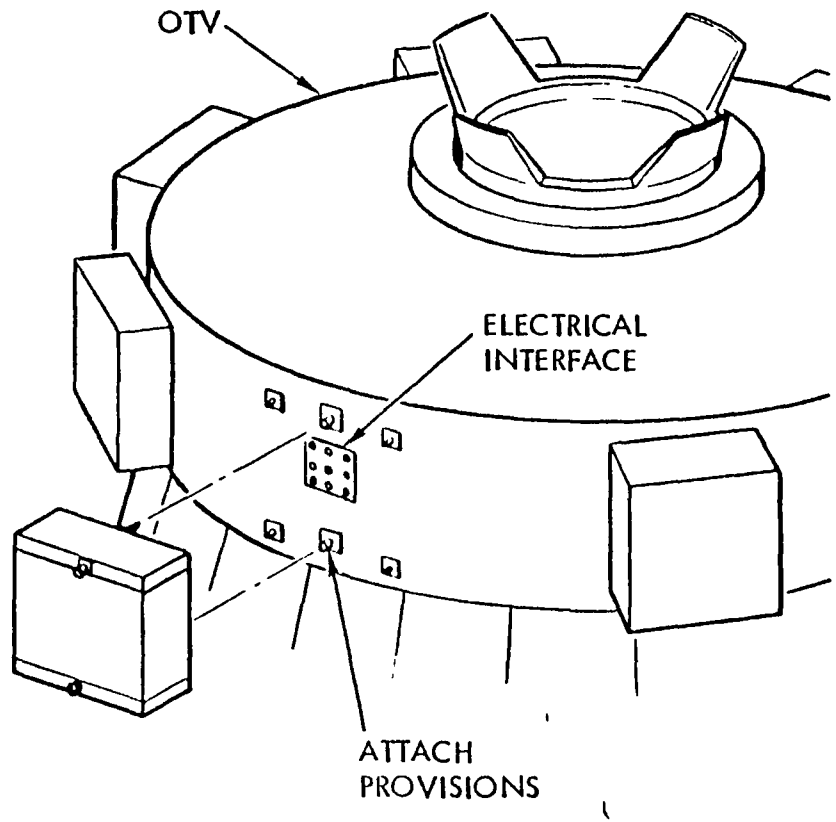
OTV SYSTEMS REPLACEMENT IMPLICATIONS

MODULAR SYSTEMS PACKAGES AS LRU'S



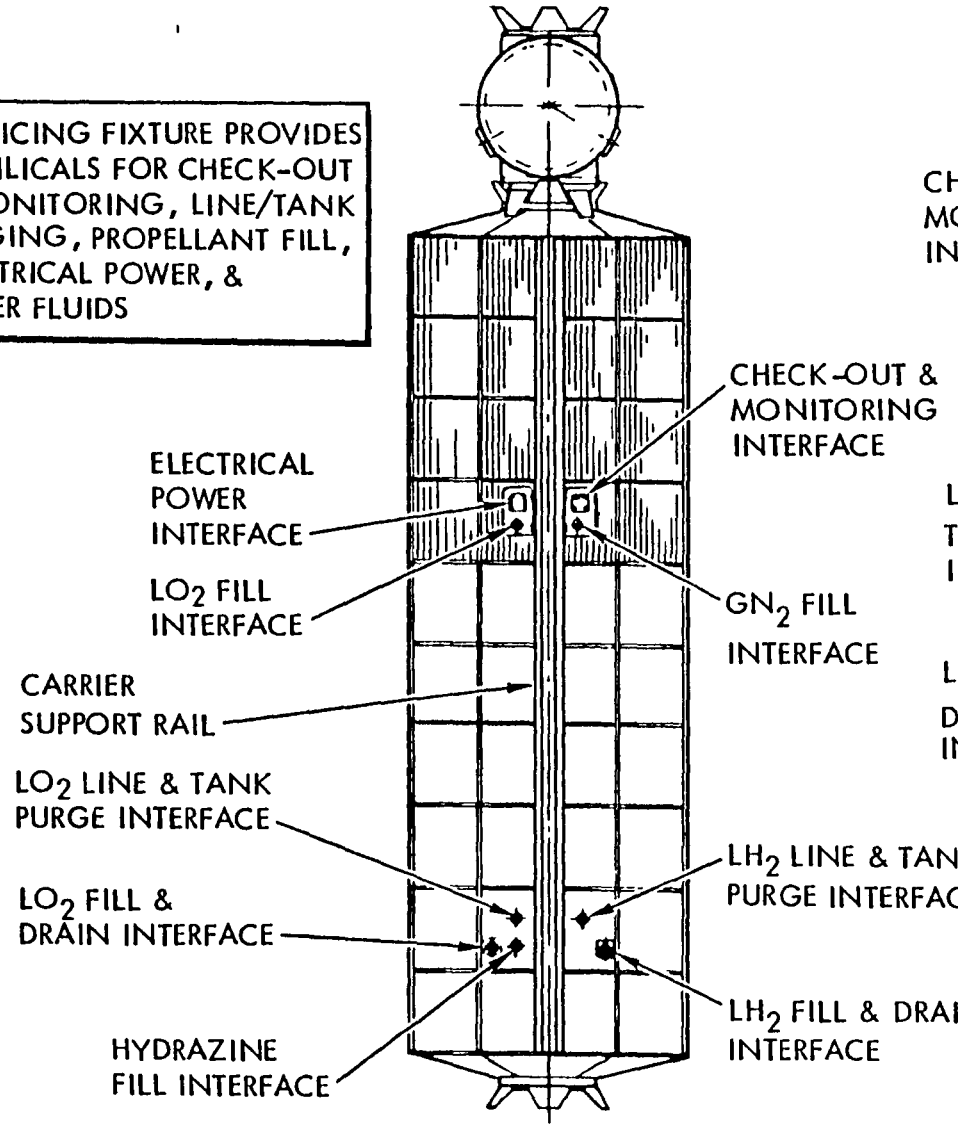
IMPLICATIONS

- ATTACH & INTERFACE PROVISIONS REQUIRED



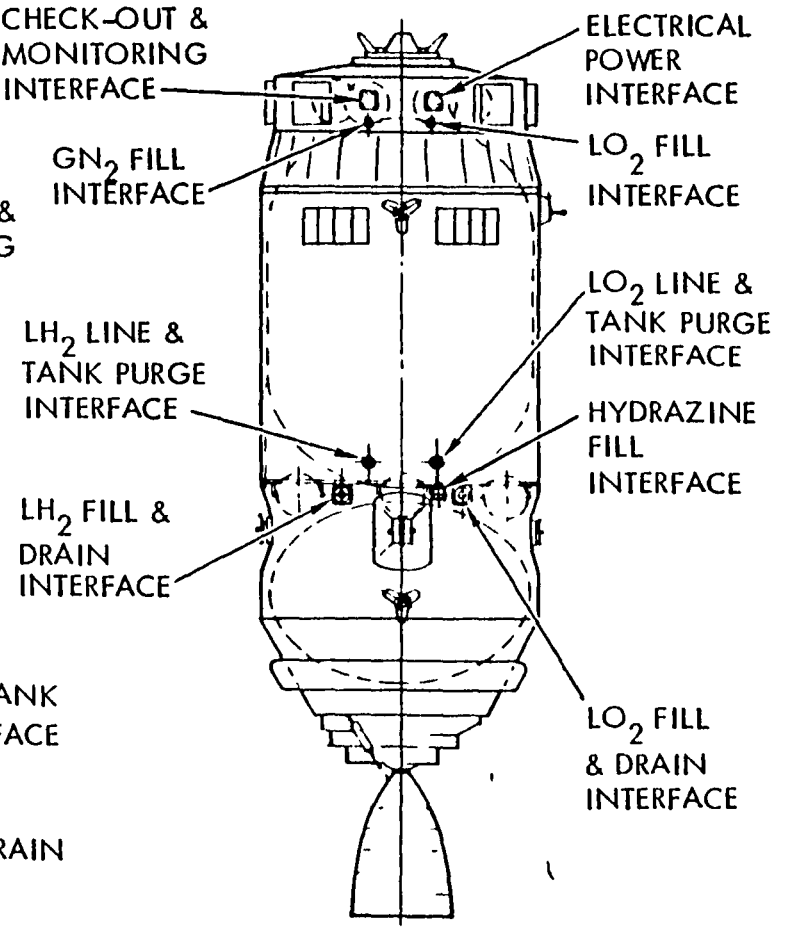
OTV SERVICING FACILITIES IMPLICATIONS

SERVICING FIXTURE PROVIDES UMBILICALS FOR CHECK-OUT & MONITORING, LINE/TANK PURGING, PROPELLANT FILL, ELECTRICAL POWER, & OTHER FLUIDS

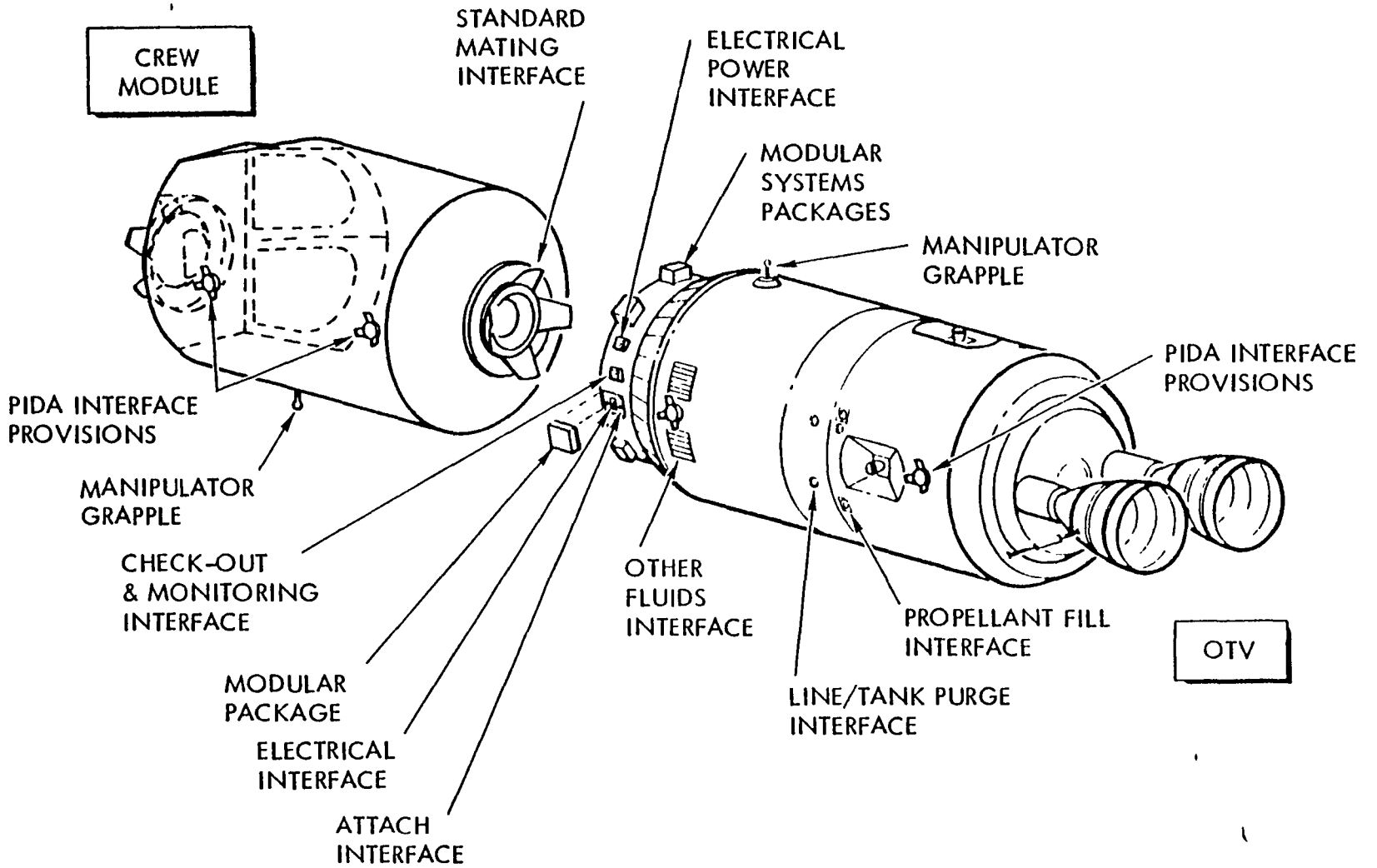


IMPLICATIONS

- SERVICES UMBILICAL INTERFACES REQUIRED



OTV IMPLICATIONS



CONCLUSIONS—SOC

OPERATIONAL IMPLICATIONS

- ORBITAL ALTITUDE—COORDINATION WITH SOLAR ACTIVITY & LOGISTICS TRAFFIC
- AUXILIARY ATTITUDE CONTROL FOR UNTENDED SOC ASSEMBLY ARRANGEMENTS
- SOC ASSEMBLY ALIGNMENT UTILIZING TV CAMERA AND TARGET

DESIGN IMPLICATIONS

- RUNAWAY JET PLUME FORCES, HEATING, CONTAMINATES
- RUNAWAY JET FORCES WHEN DOCKED
- ATTITUDE CONTROL SYSTEM TO ACCEPT DOCKED RUNAWAY JET FORCES
- SOC CONTROL CENTER IN PRESSURE VOLUME 1

BENEFITS

- VARIABLE ALTITUDE STRATEGY SAVES LOGISTICS COSTS
- STANDARD INTERFACE APPLICABLE TO OTHER SPACE PROGRAMS
- PROPELLANT STORAGE SAVES PROPELLANT LOGISTICS & IMPROVES SHUTTLE UTILIZ.
- FLIGHT SUPPORT FACILITY CONCEPT SIMPLIFIES GROWTH CAPABILITY

CONCLUSIONS—SHUTTLE

OPERATIONAL IMPLICATIONS

- DOCKING/BERTHING CONTROL PROCEDURES
- RUNAWAY JET CONTROL PROCEDURES

DESIGN IMPLICATIONS

- DOCKING MODULE/TUNNEL ADAPTER/ PAYLOAD BAY INTERFACES
- PROVISIONS FOR 8 PASSENGERS
- ADDITIONAL LIGHTS

BENEFITS

- LOGISTICS TRANSPORT—MINIMUM TURNAROUND

CONCLUSIONS—OTV

OPERATIONAL IMPLICATIONS

- DOCKING CONTROL FOR SERVICE FIXTURE MATING
- SERVICING UMBLICAL INTERFACES ARRANGEMENT

DESIGN IMPLICATIONS

- SUBSYSTEM MODULAR PACKAGE ARRANGEMENT
- STANDARD MATING INTERFACE
- PIDA INTERFACE

BENEFITS

- SIMPLIFY SERVICING OPERATIONS
- SIMPLIFY MATING OPERATIONS

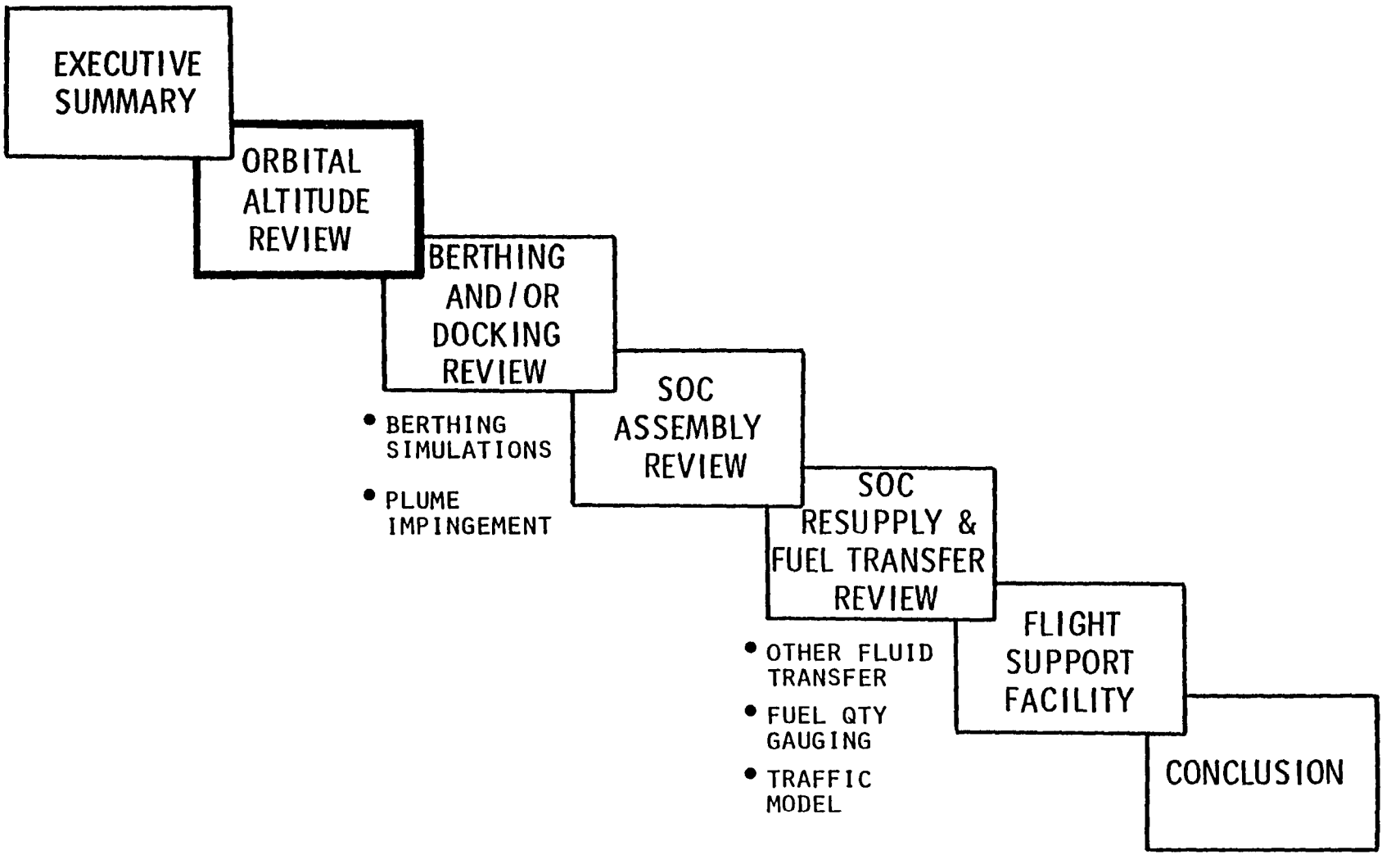
FUTURE TASKS

- ESTABLISH CONTROL ALGORITHMS FOR DETERMINATION OF OPERATIONAL FLIGHT ALTITUDES
- PERFORM SIMULATIONS TO VERIFY SOC ASSEMBLY OPERATIONS AND AIDS
- PERFORM REAL-TIME MAN-IN-THE-LOOP SIMULATIONS OF DOCKING AND BERTHING OPERATIONS
- DETERMINE THE FEASIBILITY/COMPLEXITY OF ELIMINATING SINGLE-POINT RUNAWAY JET FAILURE
- ASSESS PLUME AFFECTS TO SOC
- DETERMINE IMPLICATIONS OF RECOVERING UNUSED PROPELLANT FROM SHUTTLE EXTERNAL TANK
- FURTHER DEFINE FUEL TRANSFER SYSTEM
- DEFINE A PROPELLANT STORAGE TANK CONCEPT FOR SOC AND FOR ORBITER
- DETERMINE FLIGHT SUPPORT FLUIDS, TRANSFER, AND STORAGE CONCEPTS

DEVELOPMENT ITEMS

- FURTHER DEVELOP FLIGHT SUPPORT FACILITY CONCEPT(S)
- FURTHER DEVELOP THE STANDARD MATING INTERFACE CONCEPT
- DEVELOP REMOTE ACTUATING UTILITIES CONNECTIONS
- DEVELOP DOCKING MODULE
- DEVELOP A HANDLING AND POSITIONING AID (HPA)
- DEVELOP THE PAYLOAD INSTALLATION AND DEPLOYMENT AID (PIDA)
- FURTHER DEVELOP SOC ASSEMBLY ALIGNMENT AIDS—
  TV CAMERA, TARGET, LIGHTS
- DEVELOP A MOBILE MANIPULATOR

AGENDA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ORBITAL ALTITUDE REVIEW
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FLIGHT SUPPORT FACILITY
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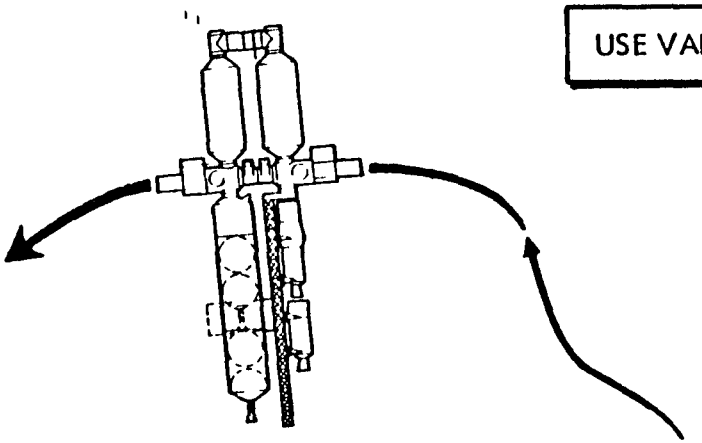
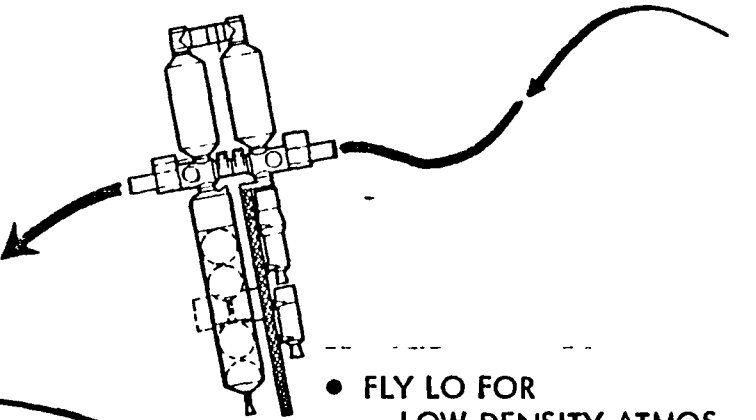
SOC ORBIT ALTITUDE STRATEGY

USE VARIABLE ALTITUDE STRATEGY

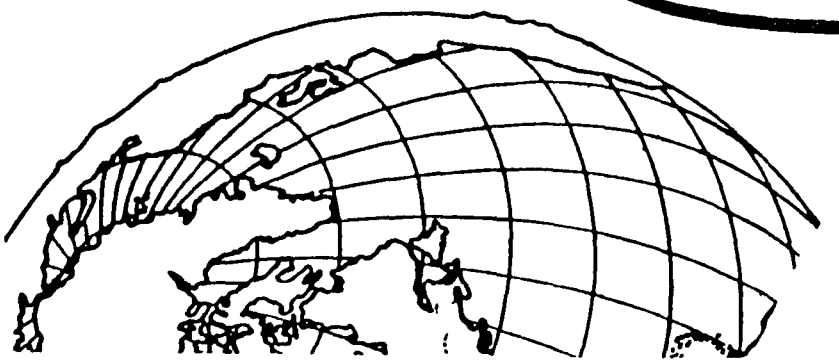


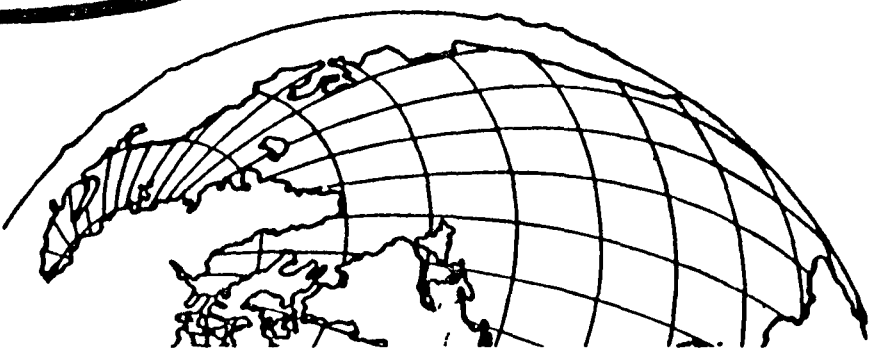
- FLY HI FOR
  HI DENSITY ATMOS
  LOW SOC TRAFFIC



- FLY LO FOR
  LOW DENSITY ATMOS
  HI SOC TRAFFIC

CAN SAVE 10 - 15 PERCENT
LOGISTICS COSTS

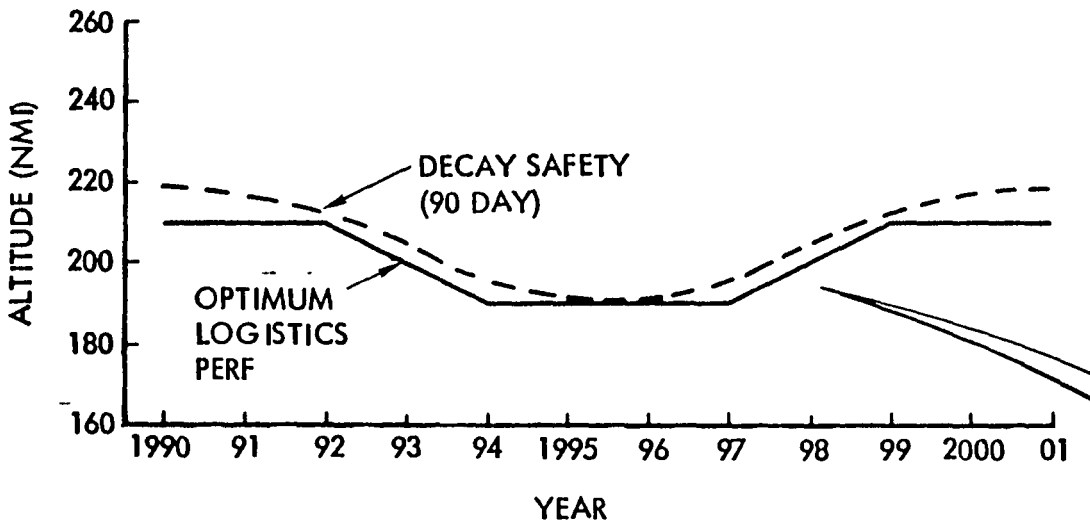




SOC OPERATIONAL ALTITUDE RANGE

- EXAMPLE ALTITUDE VARIATIONS
  - STD SHUTTLE
  - $\frac{W}{C_D A}$ = 10 PSF
  - I_{SP} = 230 SEC
  - LOGISTICS TRAFFIC = 2 SOC MASS/YR
  - ATMOS = +2σ

ATMOS	ALT NMI		
	DECAY	OPTIMUM	
		LO TRAFF	HI TRAFF
3σ MAX	236	210	210
NOMINAL MINIMUM	172	200	170



OPERATIONAL ALTITUDE RANGE

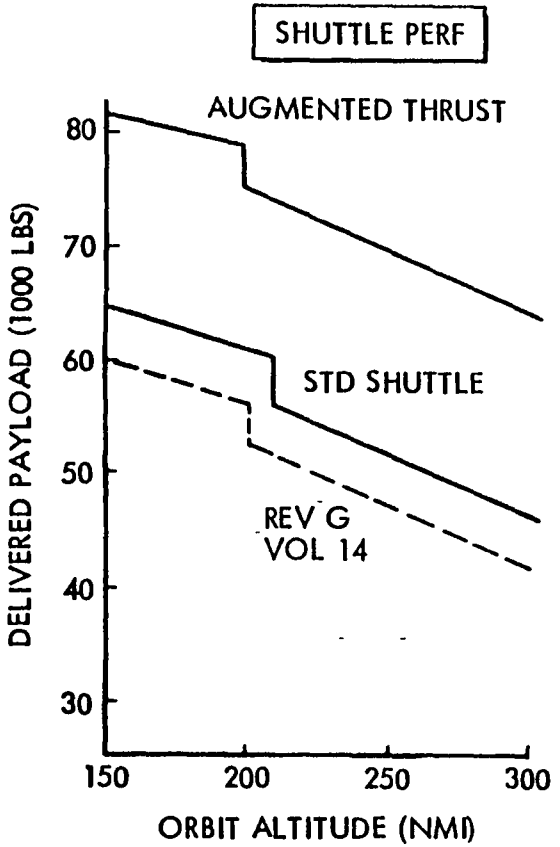
170 - 236 NMI

OMS NOT REQUIRED MOST OF THE TIME

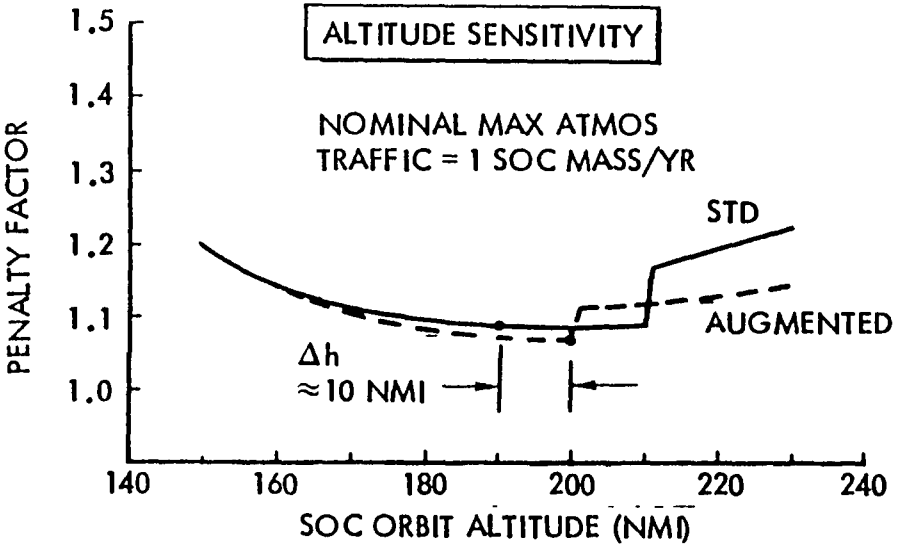
DELIVERY PERFORMANCE COMPARISON

STANDARD SHUTTLE CAN DO THE JOB

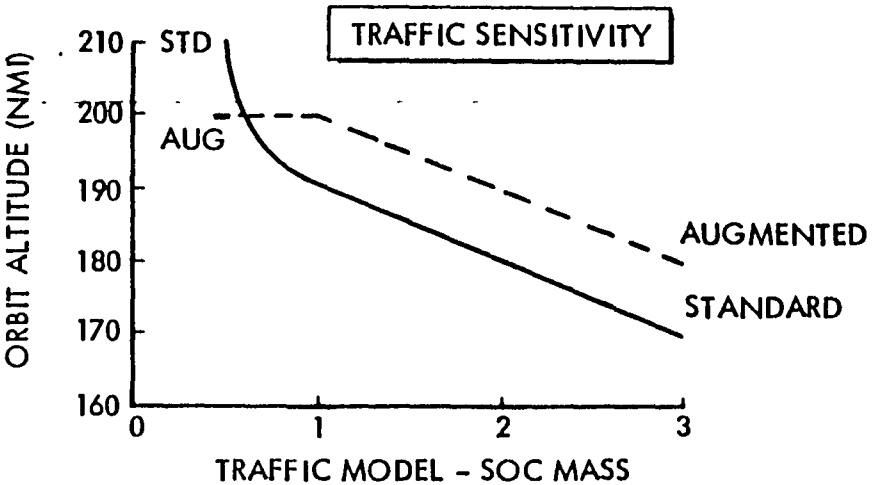
SHUTTLE PERF



ALTITUDE SENSITIVITY

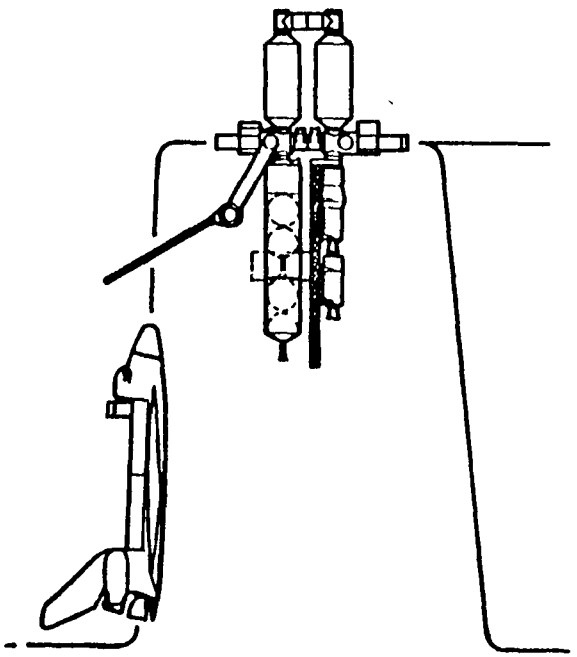


TRAFFIC SENSITIVITY



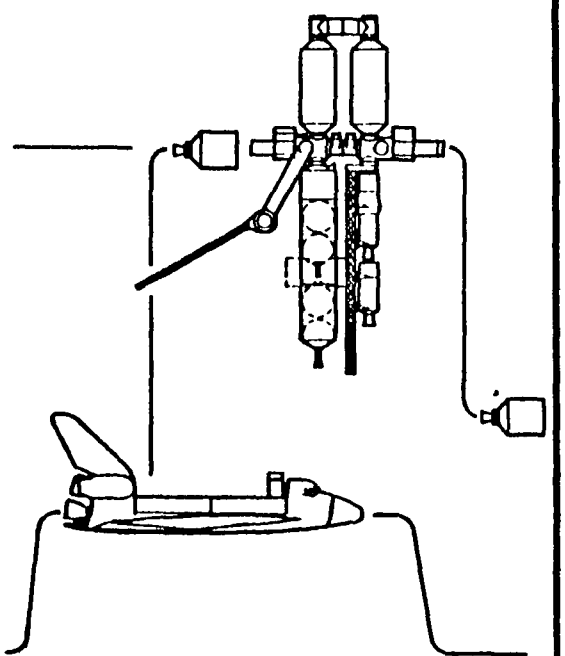
SOC LOGISTICS MODE OPTIONS

DIRECT SHUTTLE DELIVERY



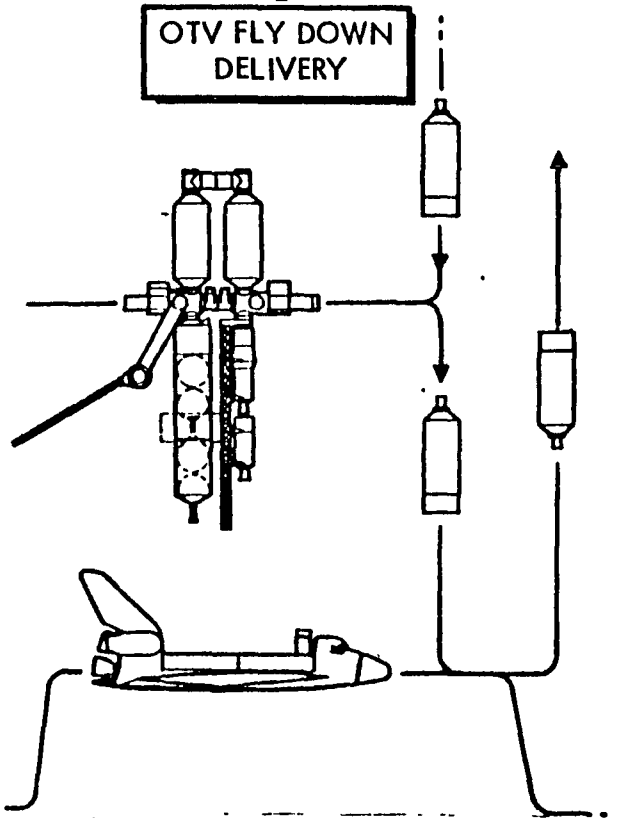
- SHUTTLE DELIVERS ALL LOGISTICS P/L's TO SOC

"TUG" ASSISTED DELIVERY



- SHUTTLE DELIVERS ALL LOGISTICS P/L's TO 150 NMI ALT
- "TUG" TRANSFERS P/L's TO SOC ALT
- "TUG" I_{SP} = 250 SEC

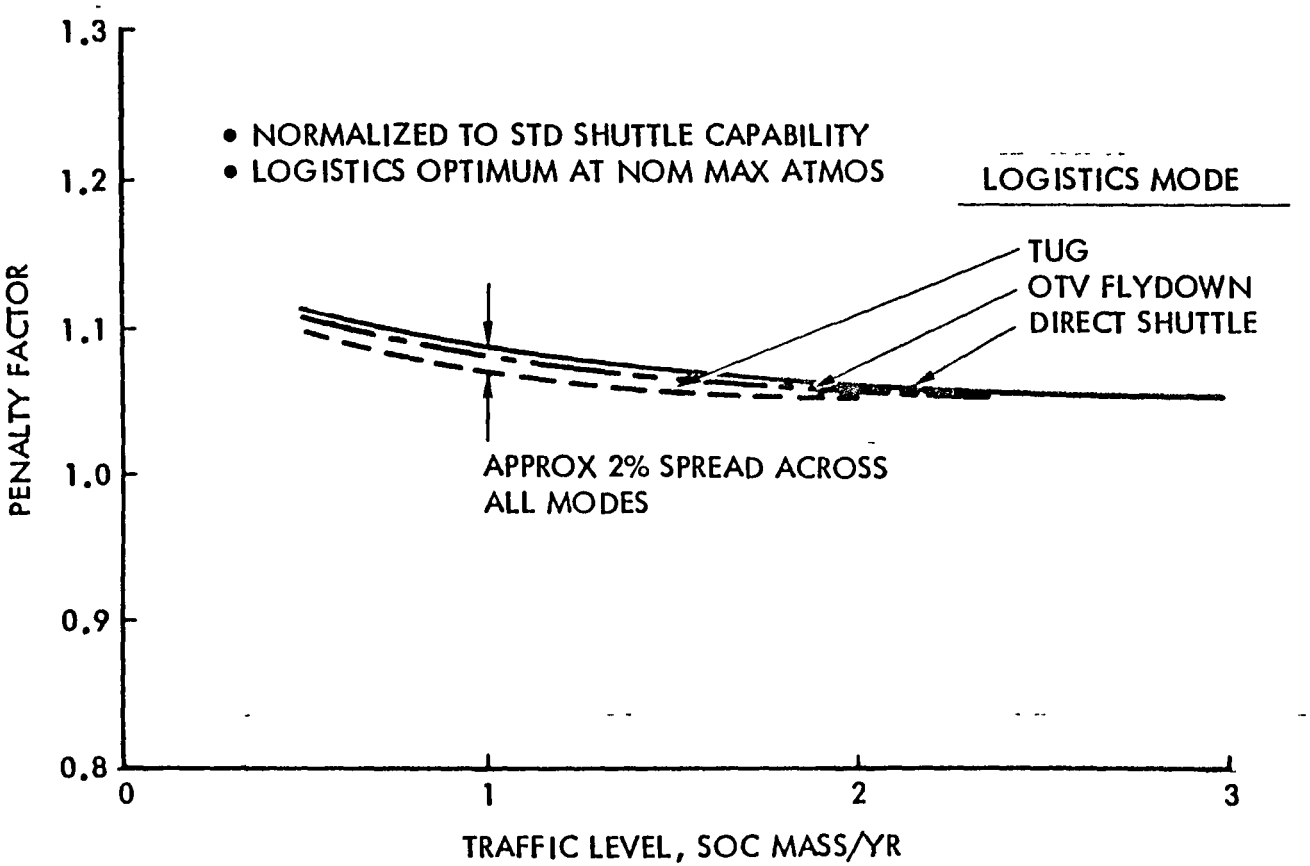
OTV FLY DOWN DELIVERY



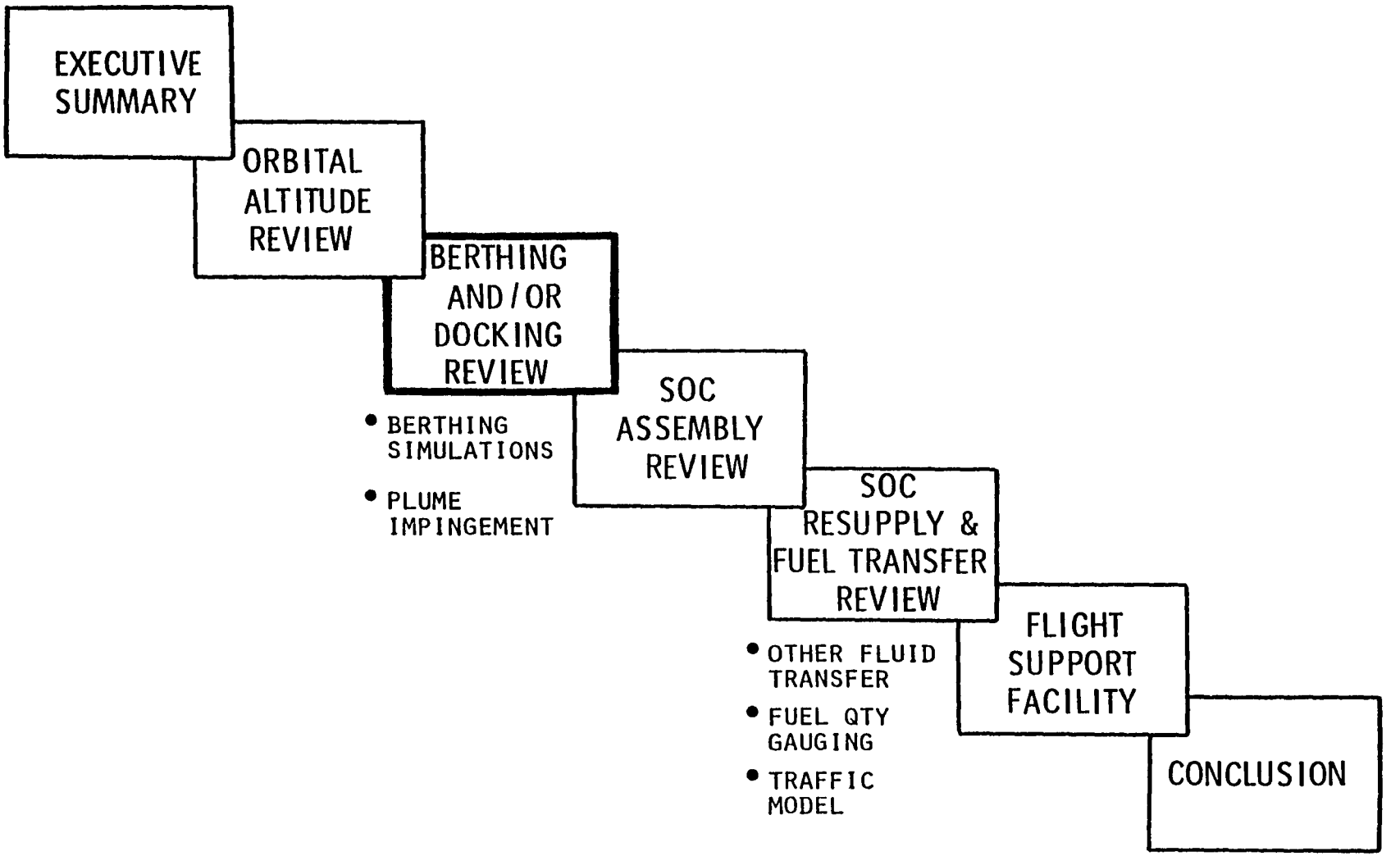
- SHUTTLE DELIVERS MAKEUP ΔV TO SOC
- SHUTTLE DELIVERS OTV P/L's & PROPELLANT TO 150 NMI
- OTV FLYS TO GEO RETURNS TO SOC, THEN FLYS DOWN TO 150 NMI
- OTV I_{SP} = 460 SEC

DELIVERY MODES COMPARISON

DIRECT SHUTTLE DELIVERY THE WAY TO GO



AGENDA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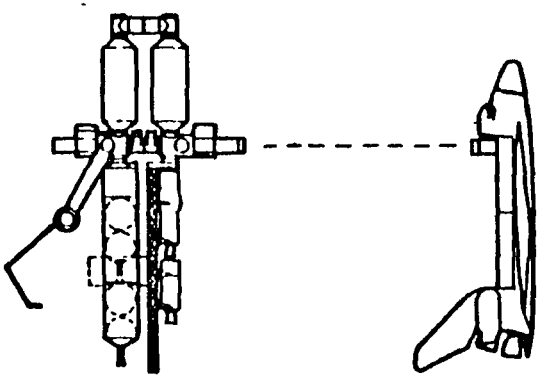
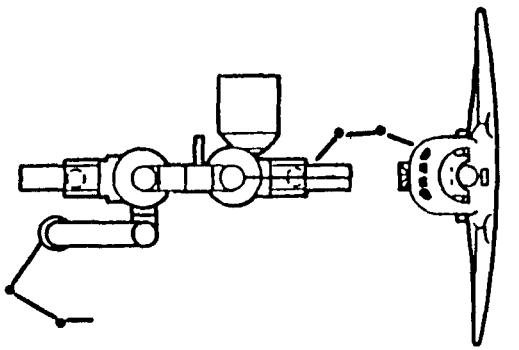
SOC REVISIT CLOSURE OPERATIONS

DIRECT DOCKING



RMS BERTHING

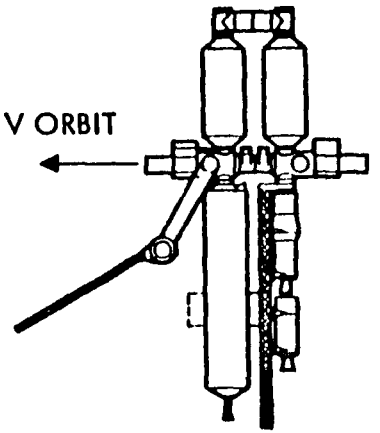


✓	ORBITER CAPABILITY	
✓	PROXIMITY OPERATIONS	✓
	RUNAWAY JET	✓
✓	PLUME IMPINGEMENT	
✓	OPERATIONAL COMPLEXITY	
✓	DOCKING MECH DESIGN	

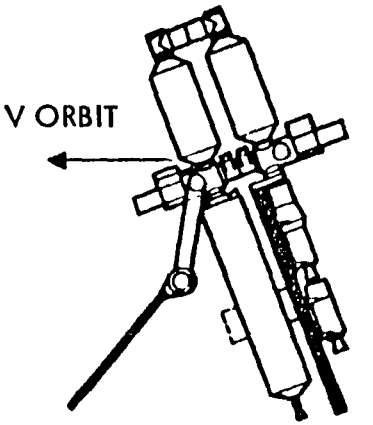
✓ RECOMMEND DIRECT DOCKING FOR SOC BASELINE

TERMINAL CLOSURE TRAJECTORY CONTROL

SOC ORTHOGONAL



TRIM ATTITUDE



MOMENTUM CONTROL REQUIREMENTS ✓

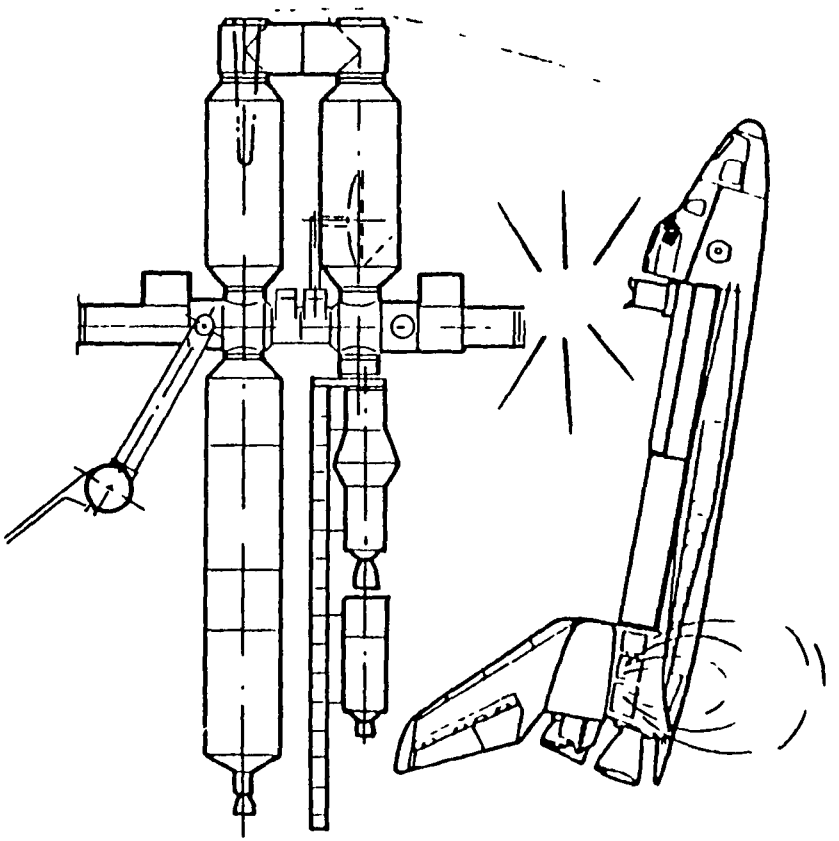
✓ ORBITER CREW PROCEDURES & TRAINING REQUIREMENTS

REAL TIME, MAN-IN-THE-LOOP SIMS REQD

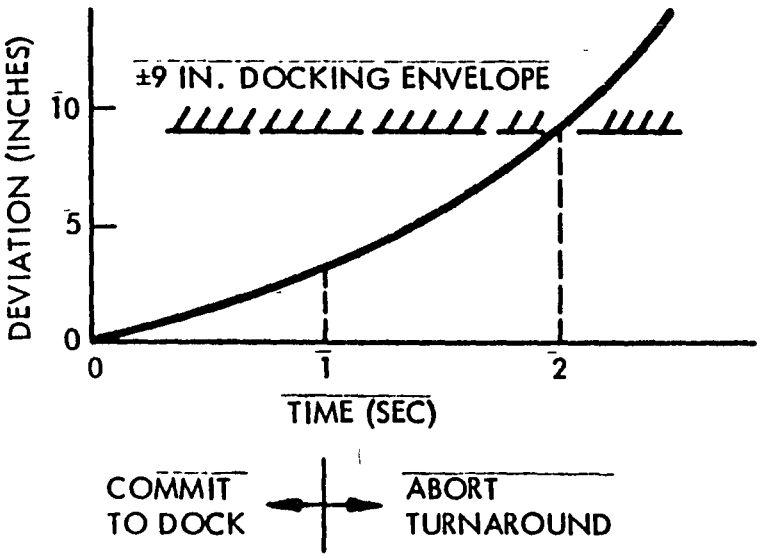
RUNAWAY JET FAILURE

PROBLEM FACTORS

- CLOSING VELOCITY
- TRAJECTORY ACCURACY
- CREW RESPONSE
- DAP MODES



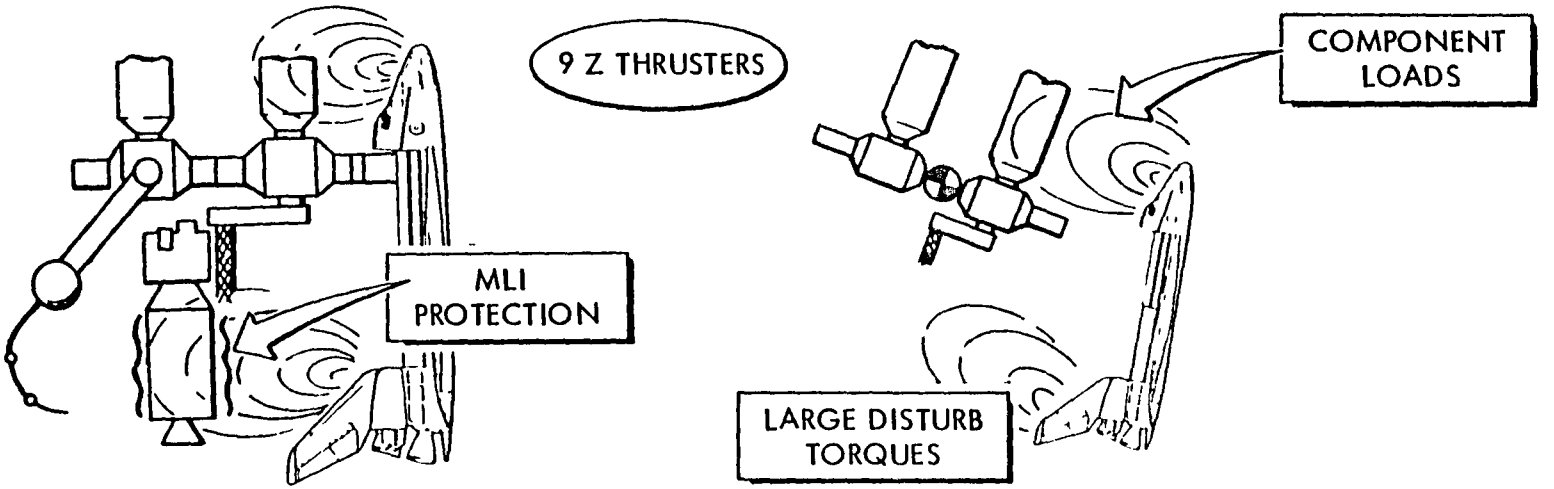
RUNAWAY Y JET



- FURTHER SIM ANAL REQD TO DEVELOP CREW PROCEDURES
- DESIGN SOC FOR JET FIRING WHILE DOCKED
- DESIGN SOC FOR HI-Z ABORT THRUST PLUMES

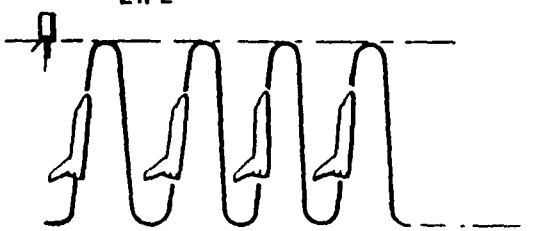
RCS PLUME ANALYSIS

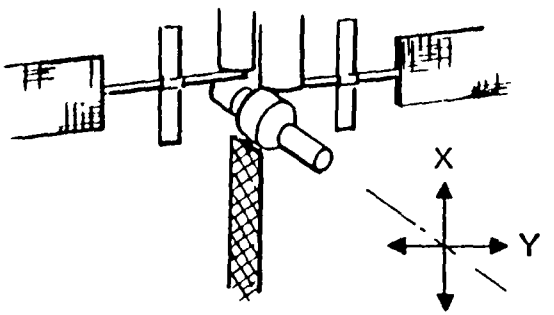
DESIGN SOC FOR HI-Z ABORT THRUSTING PLUME



CONTAMINATION FROM NORMAL RCS OPS SHOULD BE CONSIDERED

MANY REVISITS
20 YRS, PLUS
LIFE

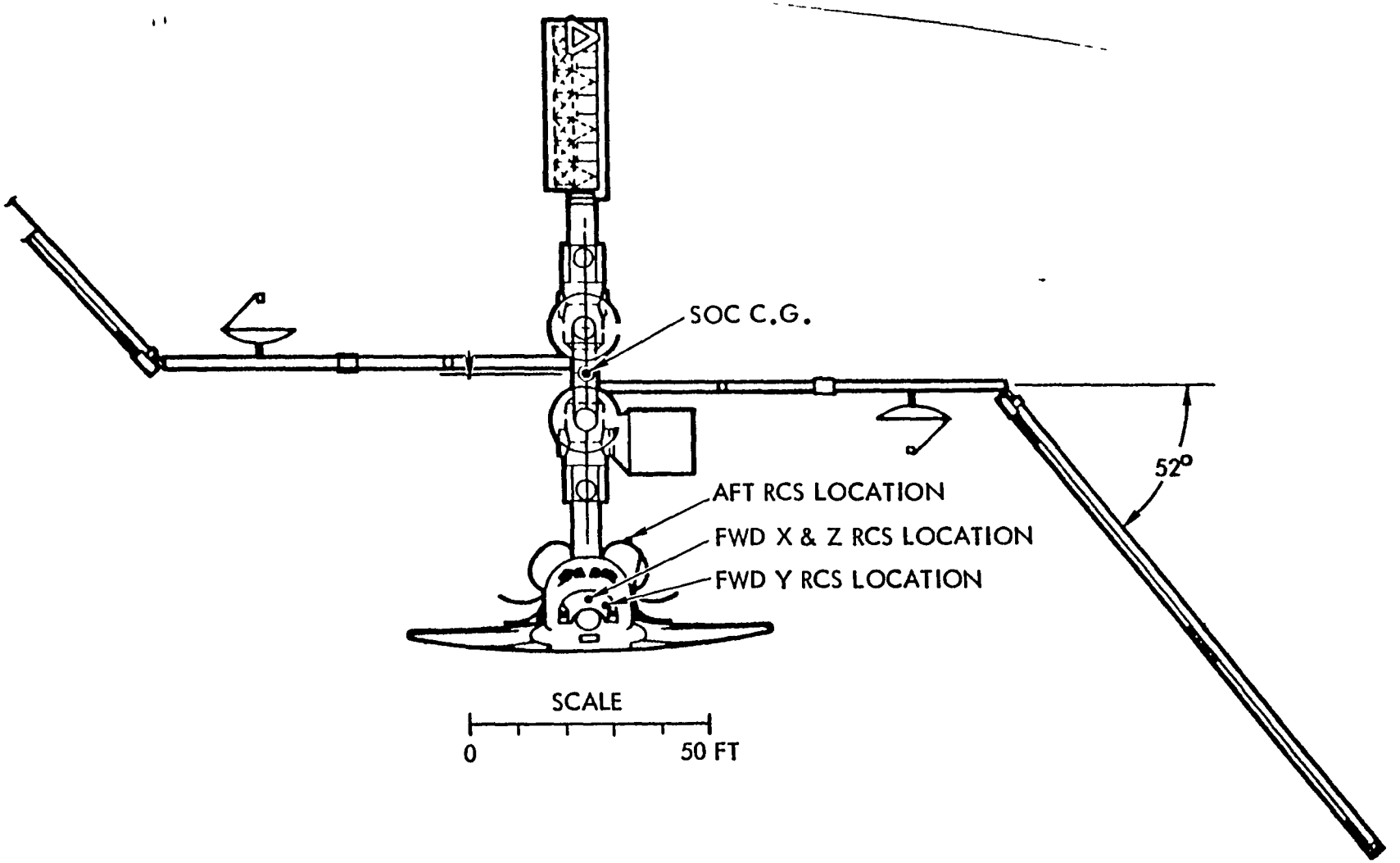




MOSTLY X & Y THRUSTING
FOR NORMAL DOCKING

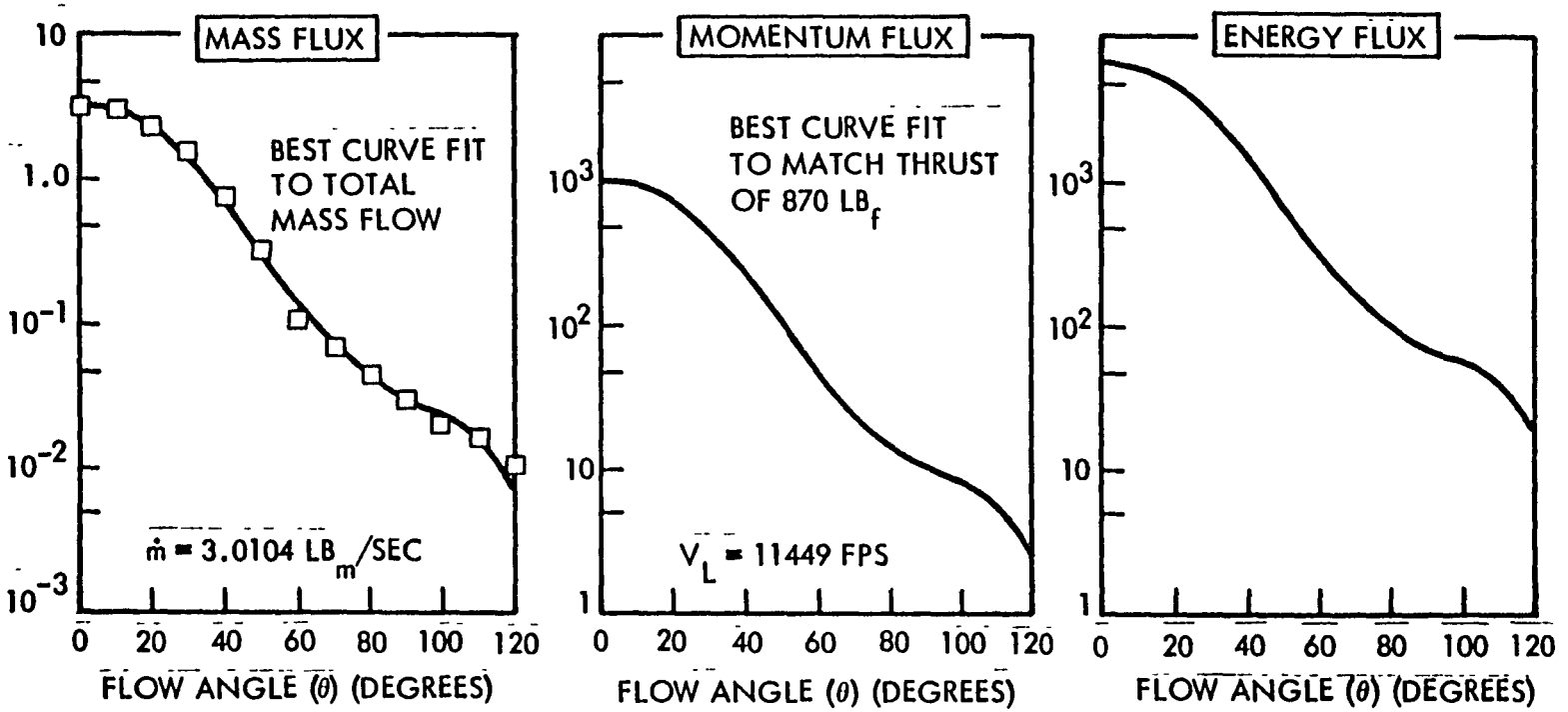
MIN IMPULSE CORRECTIONS

PLUME IMPINGEMENT GEOMETRY



PLUME ANALYSIS METHOD

SIMPLIFIED, CONSERVATIVE TECHNIQUE
2-D FLOW, AXISYMMETRIC
FAR FIELD, MULTIPLE THRUSTERS = n x SINGLE THRUSTER



$$P_n = \left[\frac{V_L}{R^2 g} \times \frac{d\dot{m}}{d\Omega}\right] \sin^2 B \qquad P_T = \left[\frac{V_L}{R^2 g} \times \frac{d\dot{m}}{d\Omega}\right] \sin B \cos B \qquad \dot{Q} = \left[\frac{V_L^2}{2R^2 Jg} \times \frac{d\dot{m}}{d\Omega}\right] \sin B$$

B = FLOW INCIDENCE ANGLE

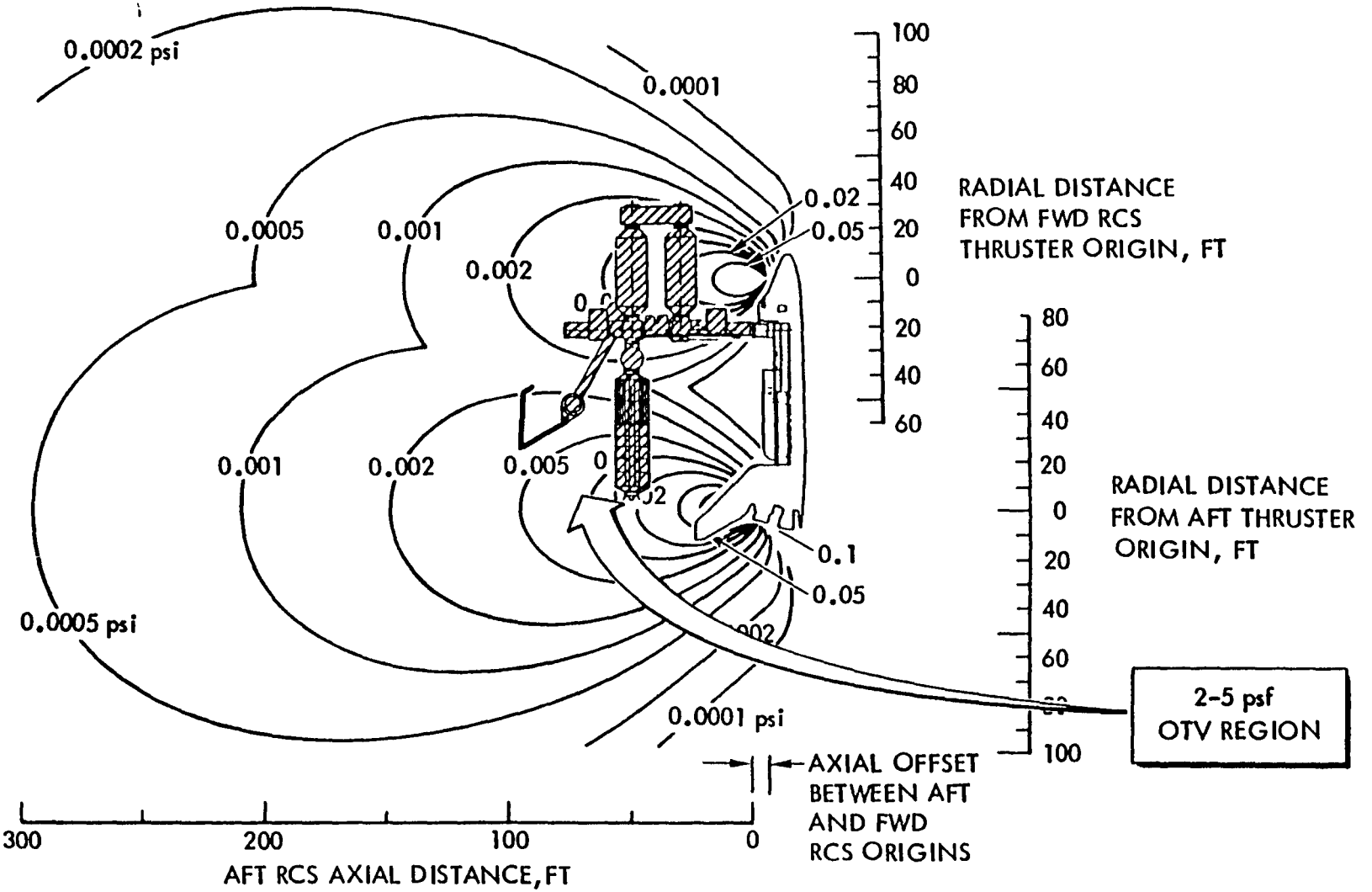
RCS PLUME IMPINGEMENT SUMMARY

DESCRIPTION	MASS DEPOSITION RATE (lbm/sec)	SOC IMPINGEMENT FORCES (lbf)			SOC MOMENTS (lbf-ft)			CONVECTIVE HEATING RATE (Btu/sec)
		F_X	F_Y	F_Z	M_X	M_Y	M_Z	
FWD RCS, 3 ENGINES (+Z DIRECTION)								
HABITABILITY MODULE NO. 1	3 146	981.1	0	41 8	0	24,058.1	0	7730.0
LOGISTICS MODULE	0 272	59 7	-11 7	-60 6	809.0	-508.2	699.0	637.7
SERVICE MODULE NO. 1	0.266	41 2	0	-29 0	0	-289.4	0	609 9
TOTAL	3.684	1082 0	-11 7	-47 8	809.0	23,260.5	699.0	
AFT RCS, 6 ENGINES (+Z DIRECTION)								
PARKED PLANETARY VEHICLE	0 354	90 6	0	50 8	0	-5,185.7	0	773 2
SAM**	2 564	867 2	0	-70 2	0	-67,579.0	0	6540.6
R/CM MODULE	0 280	60 0	23 5	39 2	1758 7	-3,255.6	-747 9	569 8
TOTAL	3 198	1017 8	23 5	19 8	1758.7	-76,020 3	-747 9	
-Y THRUSTER, 1 ENGINE								
SOLAR ARRAY (⊬ 52° ANGLE)	0 720	116 7	-171.4	-45 1	6018 4	-1957 3	19,554.1	1659.8
4 3 M ANTENNA (-Y DIRECTION)	0 036	3.2	-5 4	-0 4	123.2	55.2	220.6	45.9
RADIATORS (-Y DIRECTION)	0 009	2.3	-1.4	-0 5	35.1	20.3	79.0	20.6
TOTAL	0 765	122.2	-178 2	-46 0	6176.7	-1881 8	19,853.8	

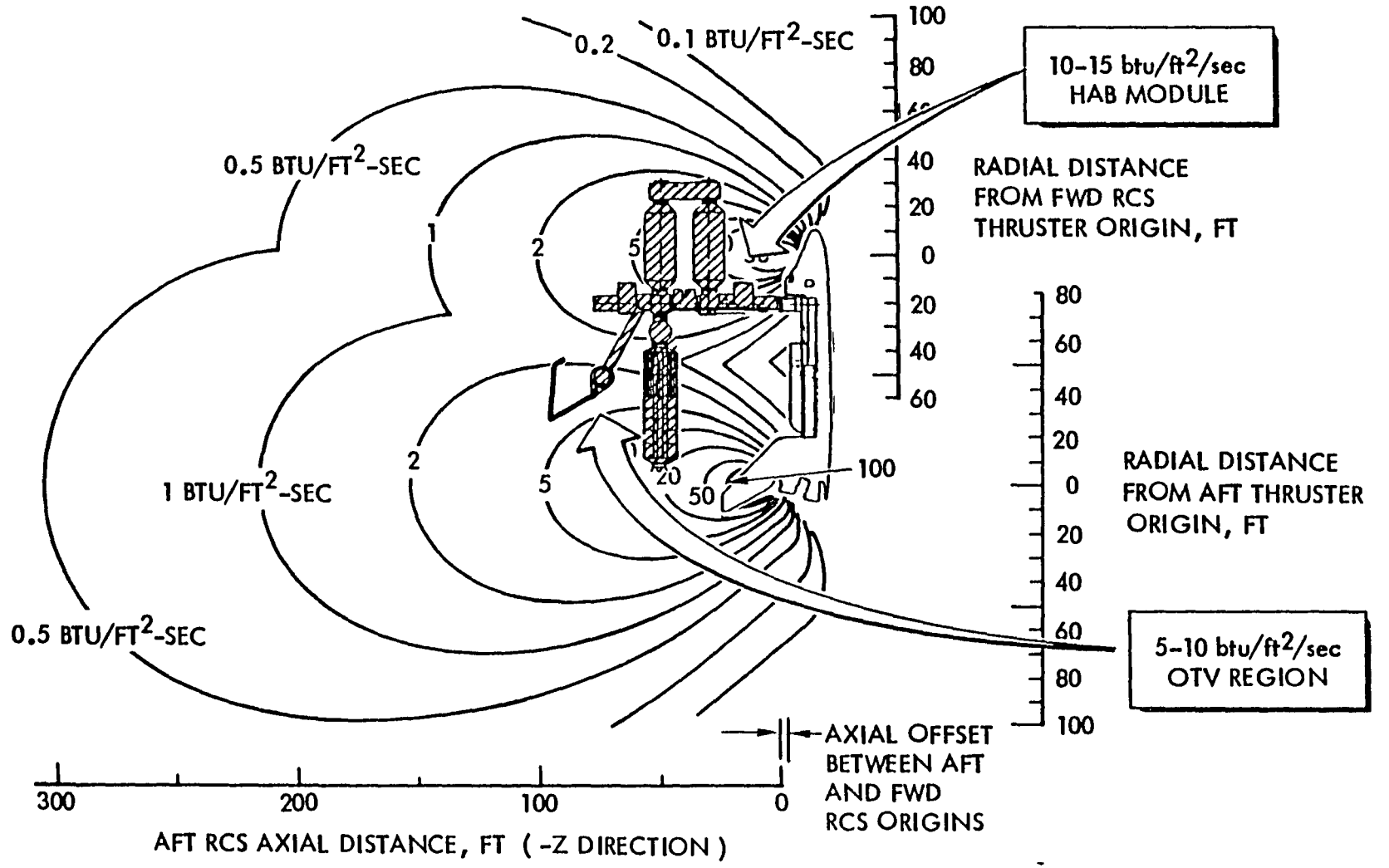
*NOTES: (1) ONE ENGINE PRODUCES 870 lb_f THRUST
(2) MASS FLOW RATE OF ONE ENGINE—3.01 lbm/sec
(3) MASS FLUX CONTAINS APPROX 9% CO_2, 17.5% CO, and 29 2% H_2O

**ASSUMED THAT THE SAM WAS OPAQUE (INTERNAL PARTS STOWAGE)

PLUME PRESSURE CONTOURS FOR 9 Z-THRUSTERS FIRING

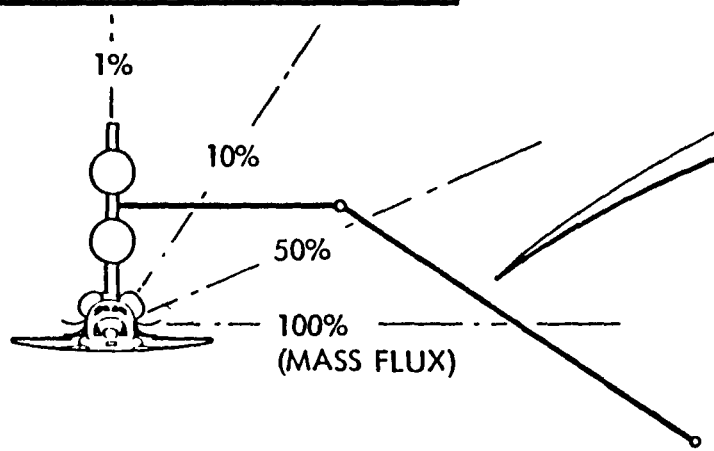


PLUME HEATING RATE CONTOURS FOR 9 Z-THRUSTER FIRING



POTENTIAL FOR PLUME INDUCED CONTAMINATION

MASS FLUX DISTRIBUTION

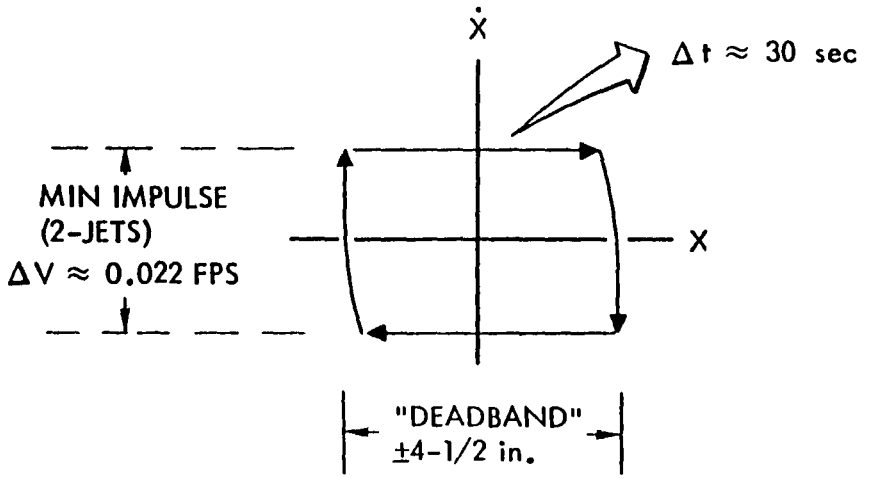


SOLAR ARRAY ≈ 1/3 STER

AVG MASS IMPINGEMENT
≈ 2 lb/sec-STER x 1/3 STER
≈ 0.7 lb/sec

TWO THRUSTERS, 80 MILLISEC
2 x 0.08 x 0.7 ≈ 0.1 lb/PULSE

DOCKING TRAJECTORY CONTROL



SAY 5 MINUTES PROX OPS PER DOCK
2 X & Y PULSES PER MINUTE

20 PULSES PER DOCK

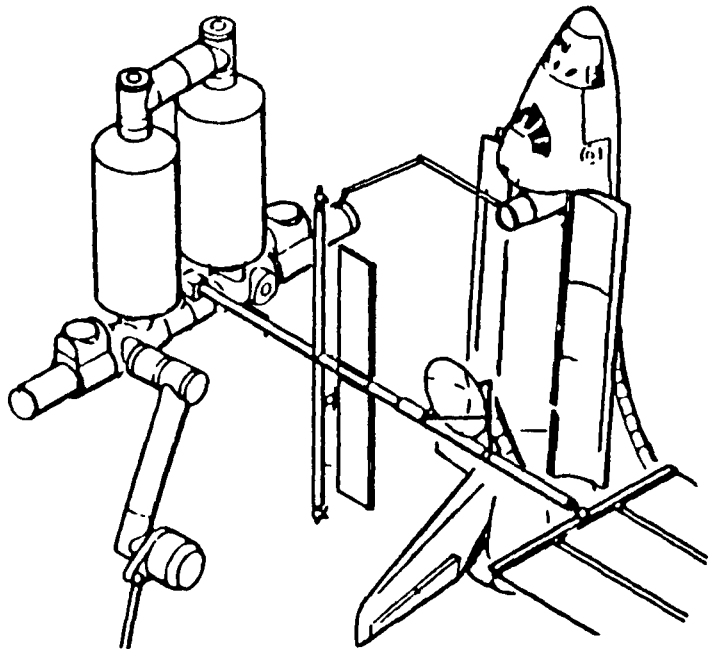
25 DOCK PER YEAR

20 YEARS LIFE

$\Sigma LB_M = (0.1)\ (20)\ (25)\ (20) = 1000$ lb

RMS BERTHING ANALYSIS

RMS BERTHING ORBITER TO SOC FEASIBLE BUT REQUIRES SOFTWARE MODS



- SPAR HI FI SIMULATIONS
- FLEXIBLE ARM DYNAMICS
- 7 SIM RUNS
  - 5 MOTION ARREST
  - 2 REPOSITION ORBITER
- NORMAL RMS MODES PRODUCE UNDAMPED OSCILLATIONS
- "MODIFIED MANUAL AUGMENTED MODE" PROVIDES STABLE CONTROL . . . FOR BOTH STOPPING & ARM MANEUVERING

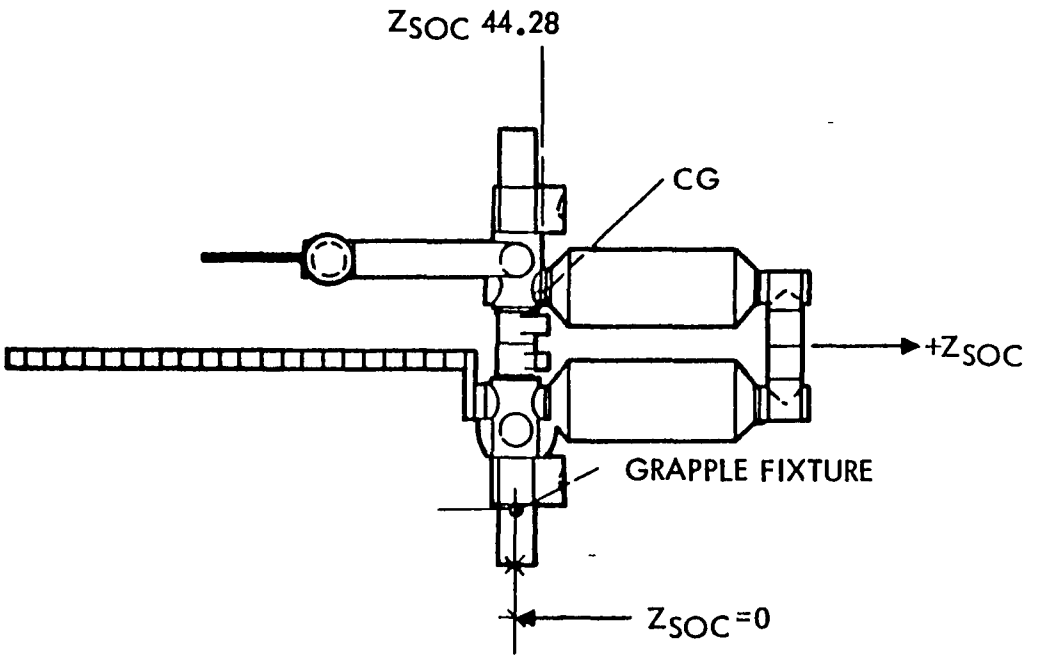
SOC MASS PROPERTIES FOR BERTHING ANALYSIS

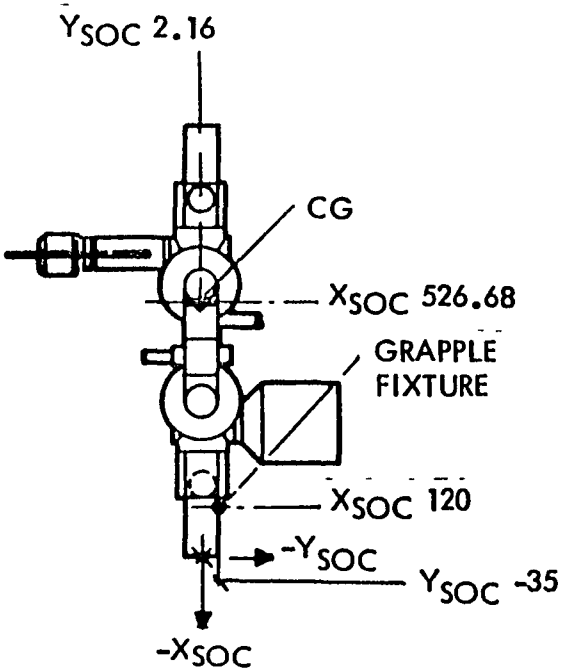
SOC CONFIGURATION
- JSC BASELINE
- NO CONSTRUCTION FIXTURE
- NO OTV
- NO PLANETARY VEHICLE

MASS (lb) 245,142

CG (in.)
- X_{SOC} = 526.68
- Y_{SOC} = 2.16
- Z_{SOC} = 44.28

INERTIAL (SLUG/ft^2)
- I_{XX} = 10,041,413
- I_{YY} = 8,269,763
- I_{ZZ} = 10,047,094
- I_{XY} = +432,403
- I_{YZ} = -251,472
- I_{ZX} = -648,327





ORBITER MASS PROPERTIES FOR BERTHING ANALYSIS

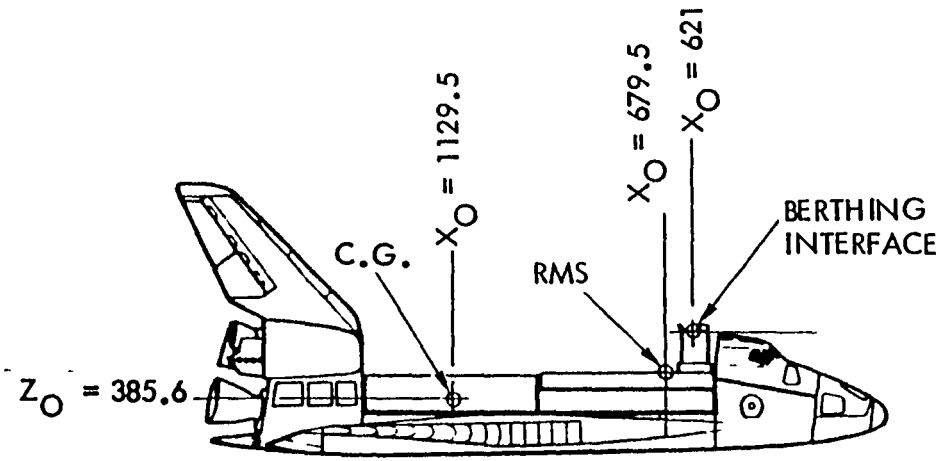
ORBITER WITH 65,000-LB PAYLOAD

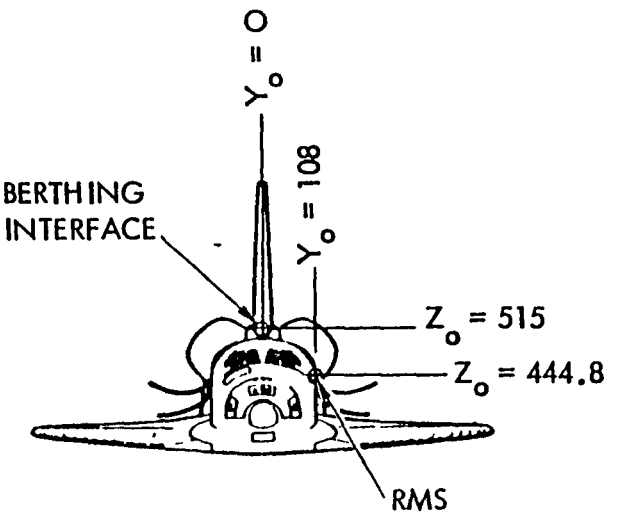
MASS = 271,700 LB

C.G. (IN.) X_O = 1129.5
Y_O = 0
Z_O = 385.6

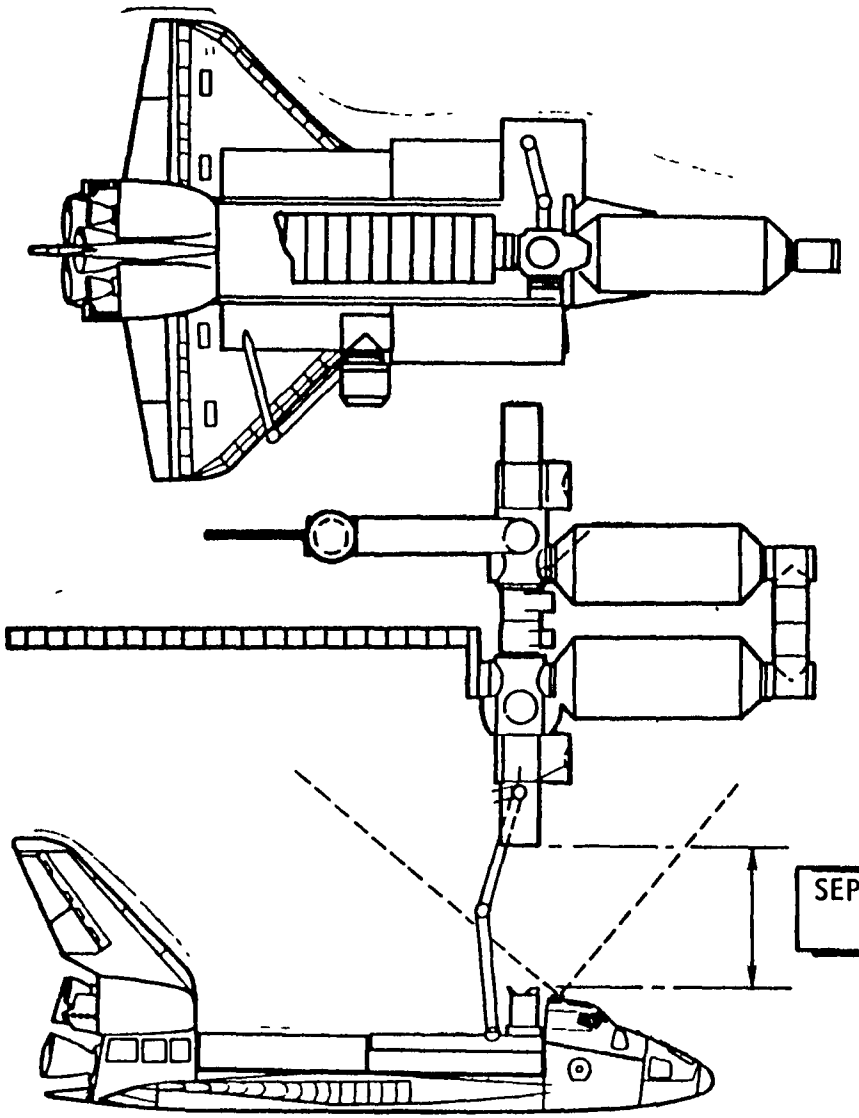
INERTIAL (SLUG FT^2)

I_{XX}	=	977,000
I_{YY}	=	7,654,000
I_{ZZ}	=	7,924,000
I_{XY}	=	2,000
I_{YZ}	=	-2,000
I_{ZX}	=	272,000



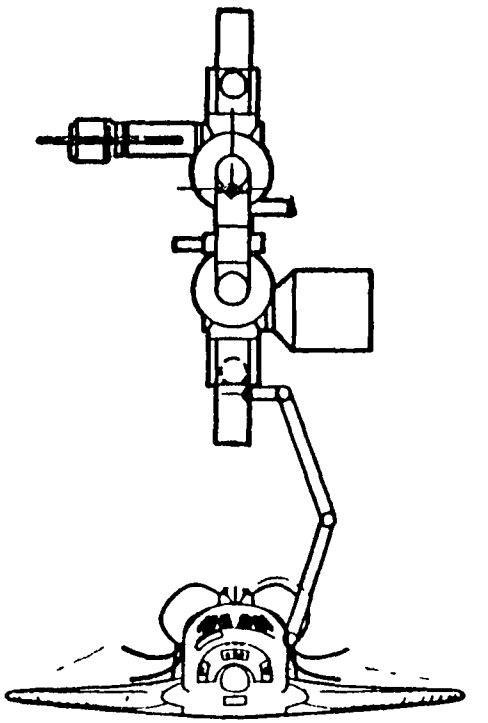


ORBITER/SOC BERTHING GEOMETRY



RMS JOINT ANGLES, DEG	
SHOULDER YAW	-108.1
SHOULDER PITCH	93.9
ELBOW PITCH	-46.1
WRIST PITCH	-68.2
WRIST YAW	17.5
WRIST ROLL	25.7

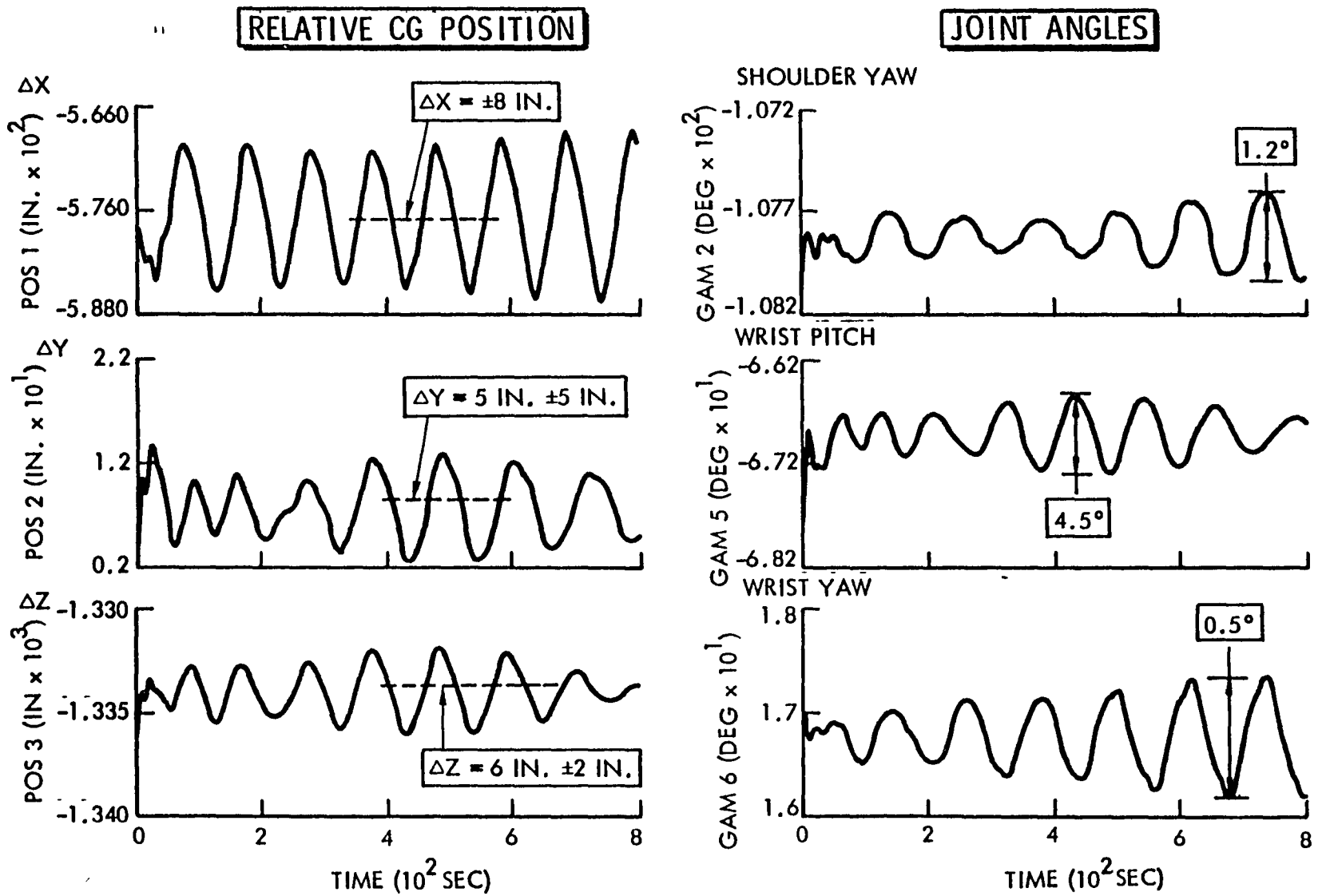
SEPARATION DISTANCE
298 in. (24.8 ft)



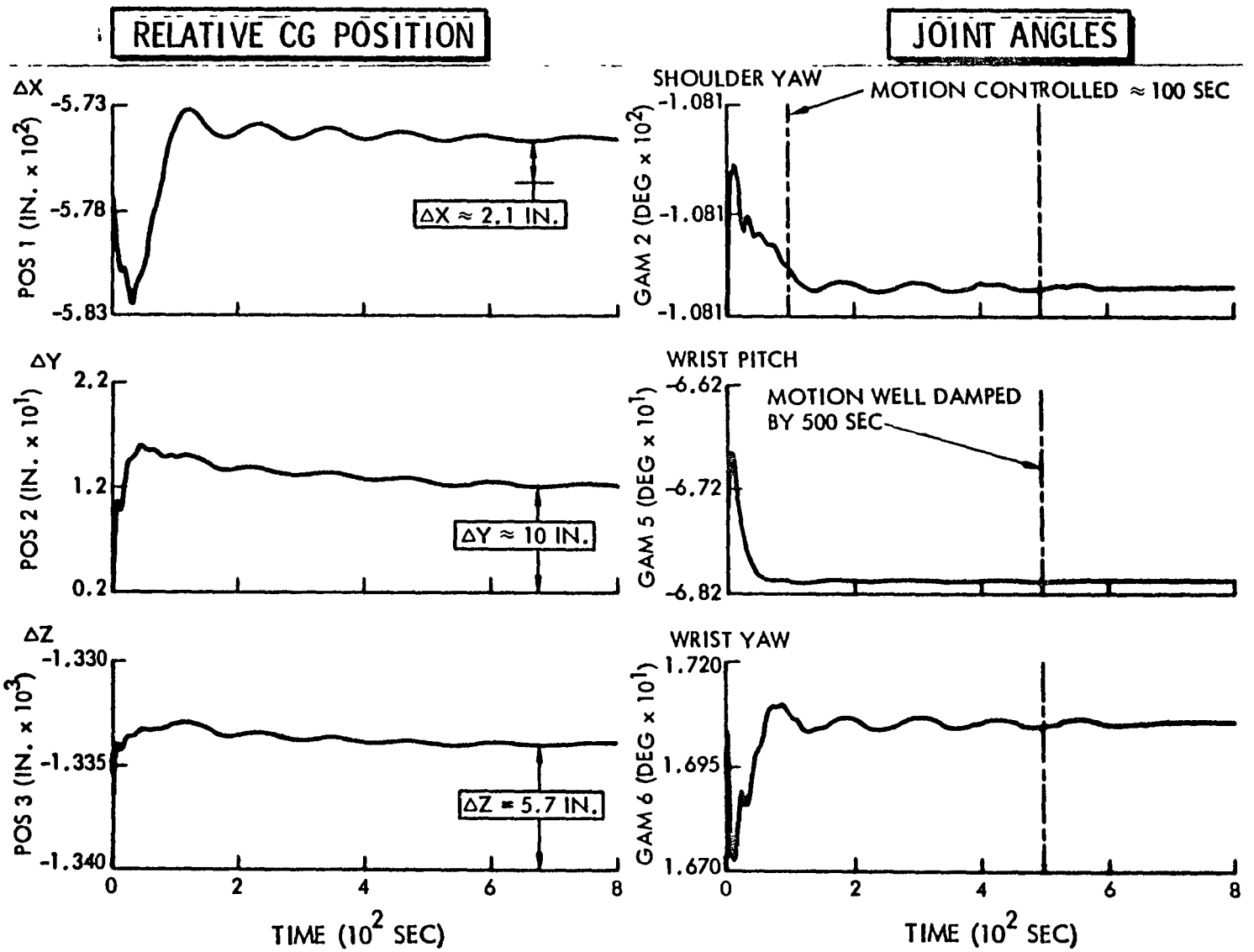
RMS BERTHING RESULTS SUMMARY

RUN	CASE CONDITIONS	SUMMARY RESULTS
1	• ARREST INITIAL MOTION (.1 ft/sec, .025°/sec) MOTION IN THE ARM PLANE • MAM/CONTROLLERS IN NEUTRAL (I.E., ZERO RATE COMMANDS)	• PHM AUTOMATICALLY ENGAGED FEW SECONDS AFTER "RIGIDIZATION" • MARGINAL STABILITY –NO APPRECIABLE DAMPING (800 sec) –SOC CENTRE OF MASS PEAK TO PEAK EXCURSIONS 1 5 ft
2	• SAME AS ABOVE WITH INITIAL MOTION PERPENDICULAR TO THE ARM PLANE	• UNDAMPED OSCILLATION
3	• ARREST INITIAL MOTION (.1 ft/sec, .025°/sec) MOTION IN THE ARM PLANE • MODIFIED MAM/CONTROLLERS IN NEUTRAL	• STABLE CONTROL EXHIBITED, AFTER 400 SECONDS –SOC CENTRE OF MASS PEAK TO PEAK EXCURSION WITHIN 1 INCH –SOC ATTITUDE EXCURSION WITHIN 0.2 DEG • RELATIVELY HIGH LOADS FOR SHORT PERIOD IMMEDIATELY AFTER RIGIDIZATION; LEVELS ACCEPTABLE
4	• SAME AS ABOVE WITH SOC INERTIA 10^7 HIGHER THAN BASELINE; SIMULATE "STOPPING PHASE" WITH SOC ACS ACTIVE	• HIGHER FREQUENCIES ARE EXHIBITED AND SLIGHTLY HIGHER LOADS, BUT STILL WITHIN ACCEPTABLE LEVELS
5	• MANEUVER SOC WITH MODIFIED MAM • INITIAL CONDITIONS FROM END OF RUN 3 • COMMAND TOWARDS "PREBERTH" POSITION/ORIENTATION	• SUITABLE STRATEGY FOR MANEUVERING THE SOC
6	• USING SLIGHTLY MODIFIED OCAS MODE –MANEUVER THE SOC TO "PREBERTH" POSITION/ ORIENTATION –STABILIZE THE SOC AT "PREBERTH" • INITIAL CONDITION FROM END OF RUN 3	• OCAS QUITE SUITABLE FOR MANEUVERING THE SOC • OCAS NOT SUITABLE FOR STABILIZING THE SOC; MARGINAL STABILITY IS EXHIBITED NEAR THE "PREBERTH" POSITION
7	• ARREST HIGH ANGULAR MOTION (052 ft/sec, .1732°/sec) • MODIFIED MAM/CONTROLLERS IN NEUTRAL	• MODIFIED MAM CONFIRMED AS THE STRATEGY FOR STOPPING AND/OR STABILIZING THE SOC

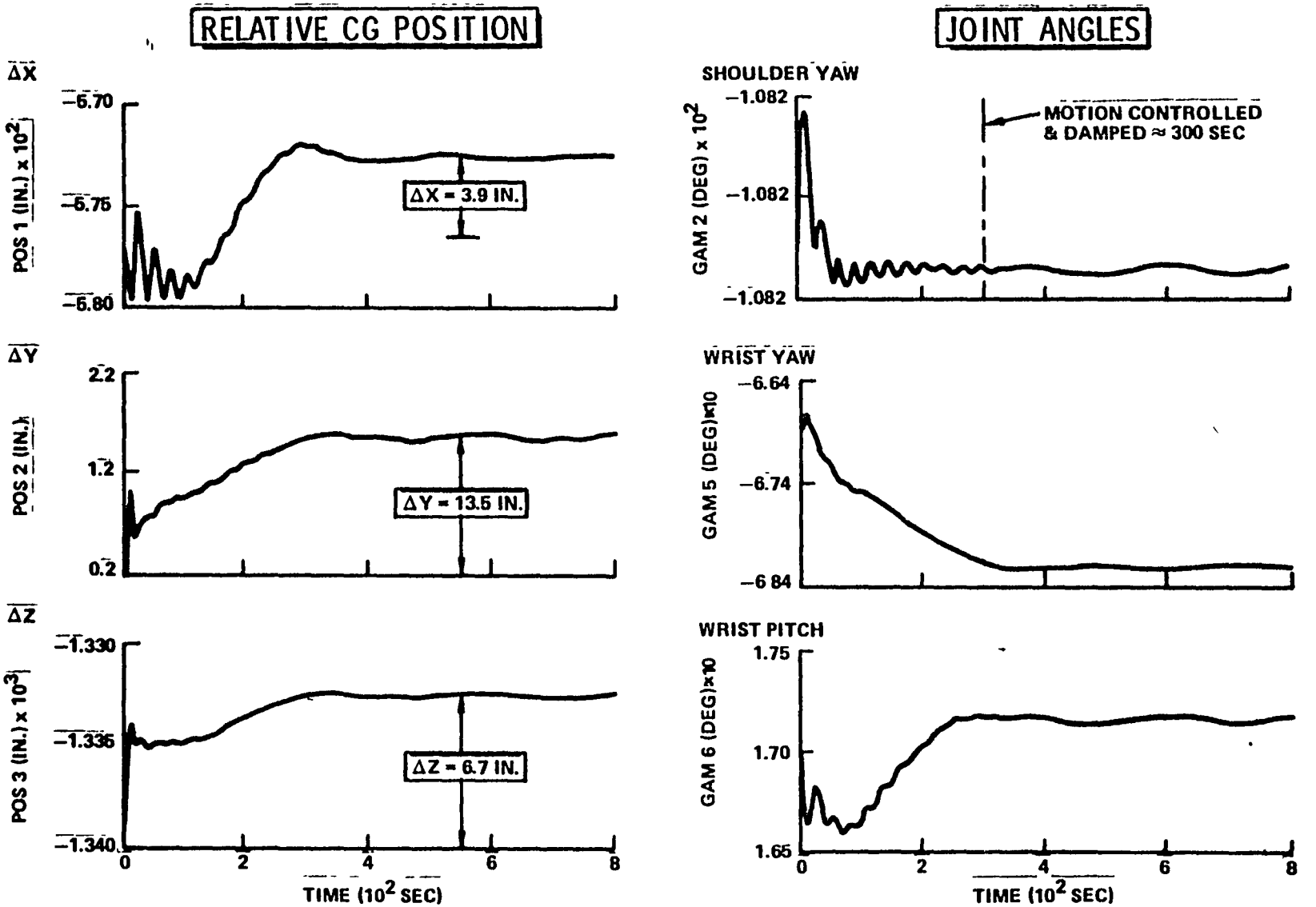
BERTHING SIMULATION RESULTS - RUN 1



BERTHING SIMULATION RESULTS - RUN 3

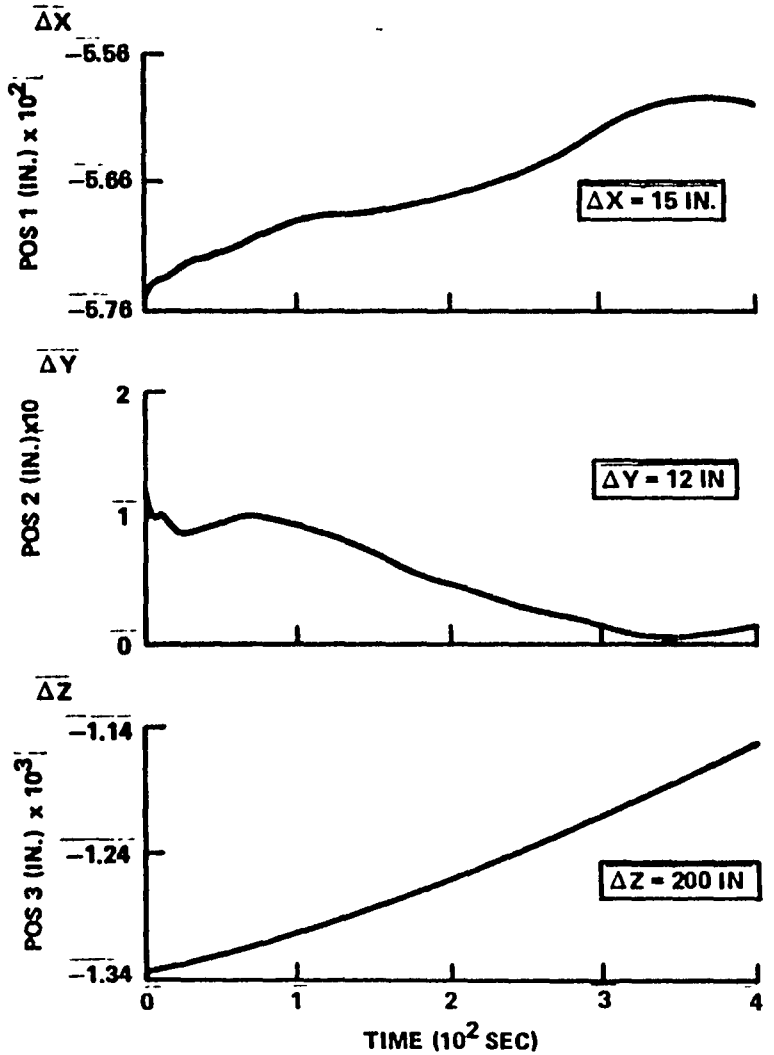


BERTHING SIMULATION RESULTS - RUN 4

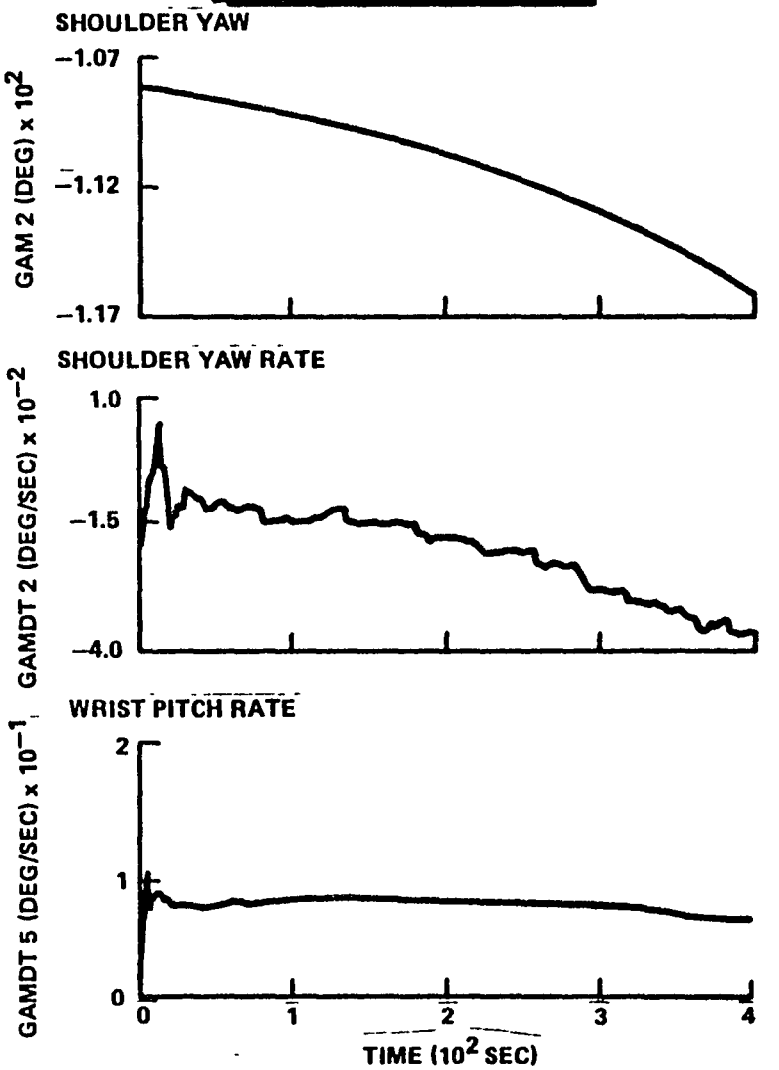


BERTHING SIMULATION RESULTS - RUN 5

RELATIVE CG POSITION

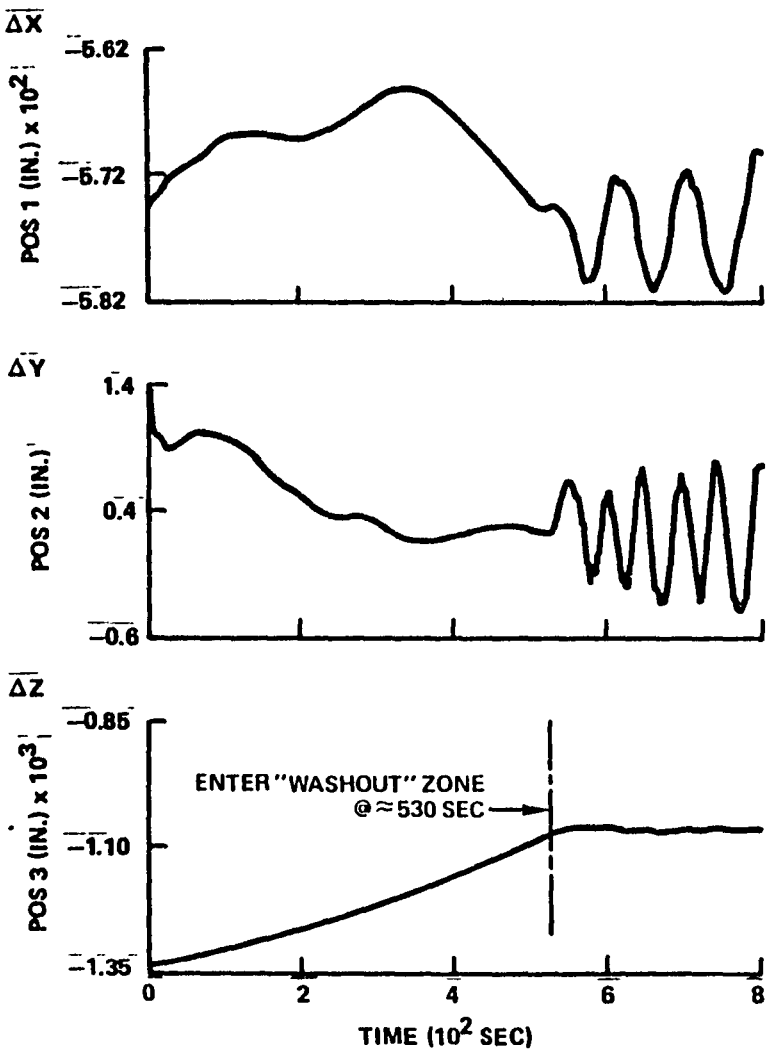


JOINT ANGLES/RATES

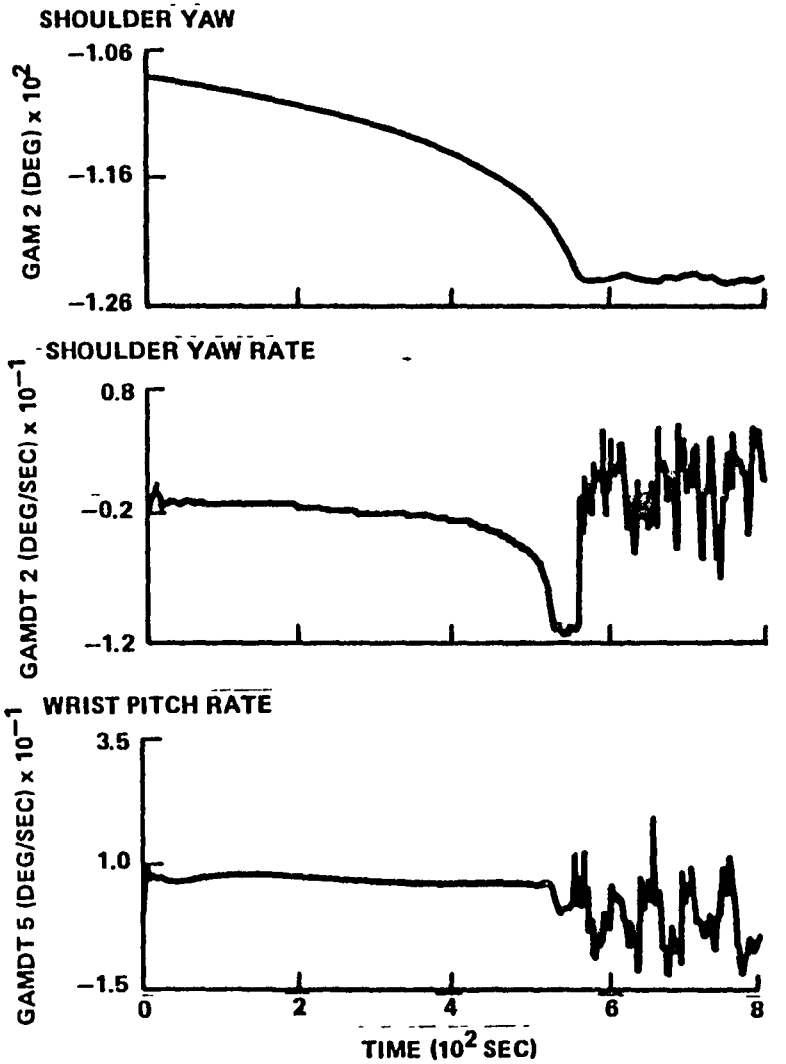


BERTHING SIMULATION RESULTS - RUN 6

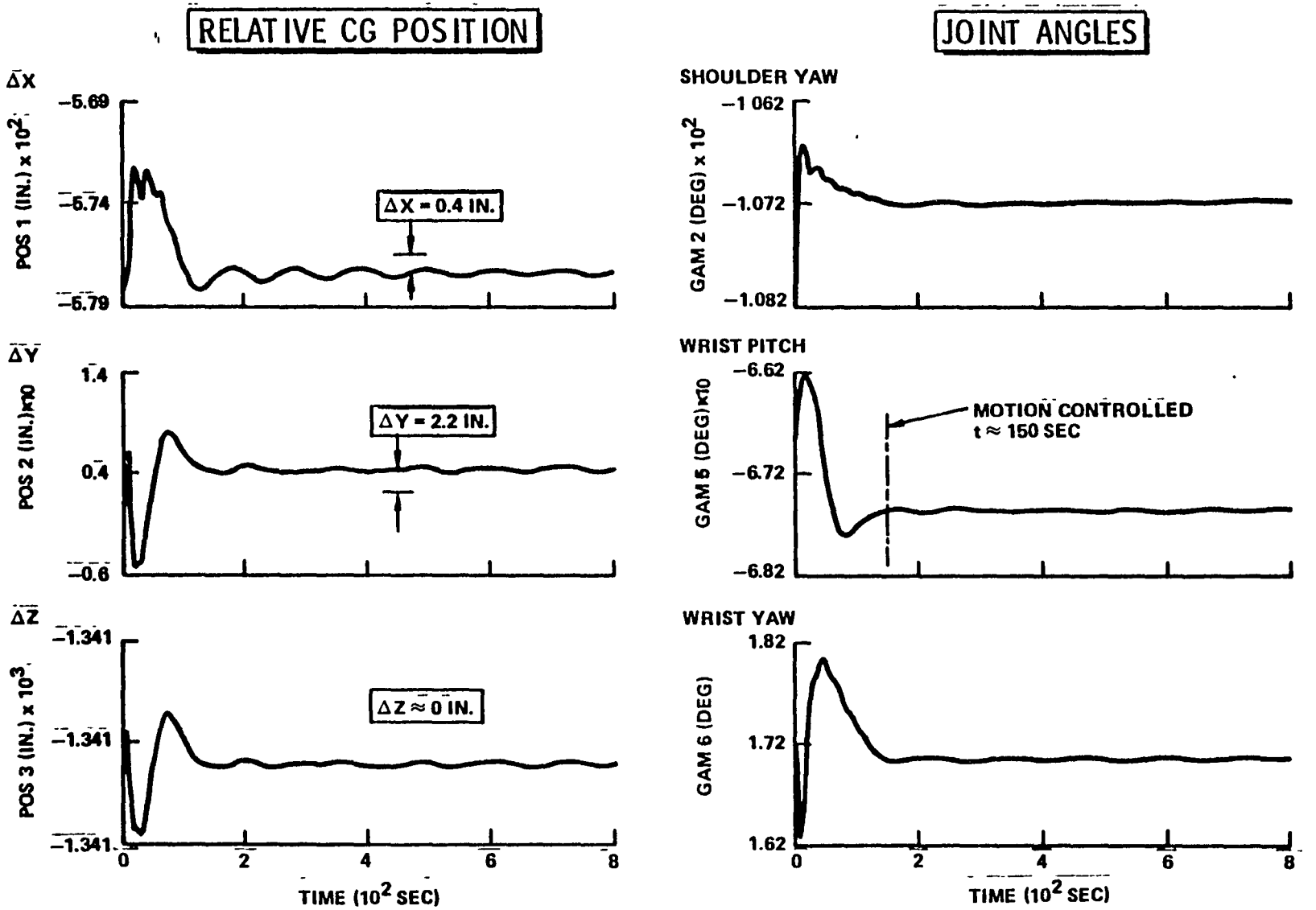
RELATIVE CG POSITION



JOINT ANGLES/RATES



BERTHING SIMULATION RESULTS - RUN 7

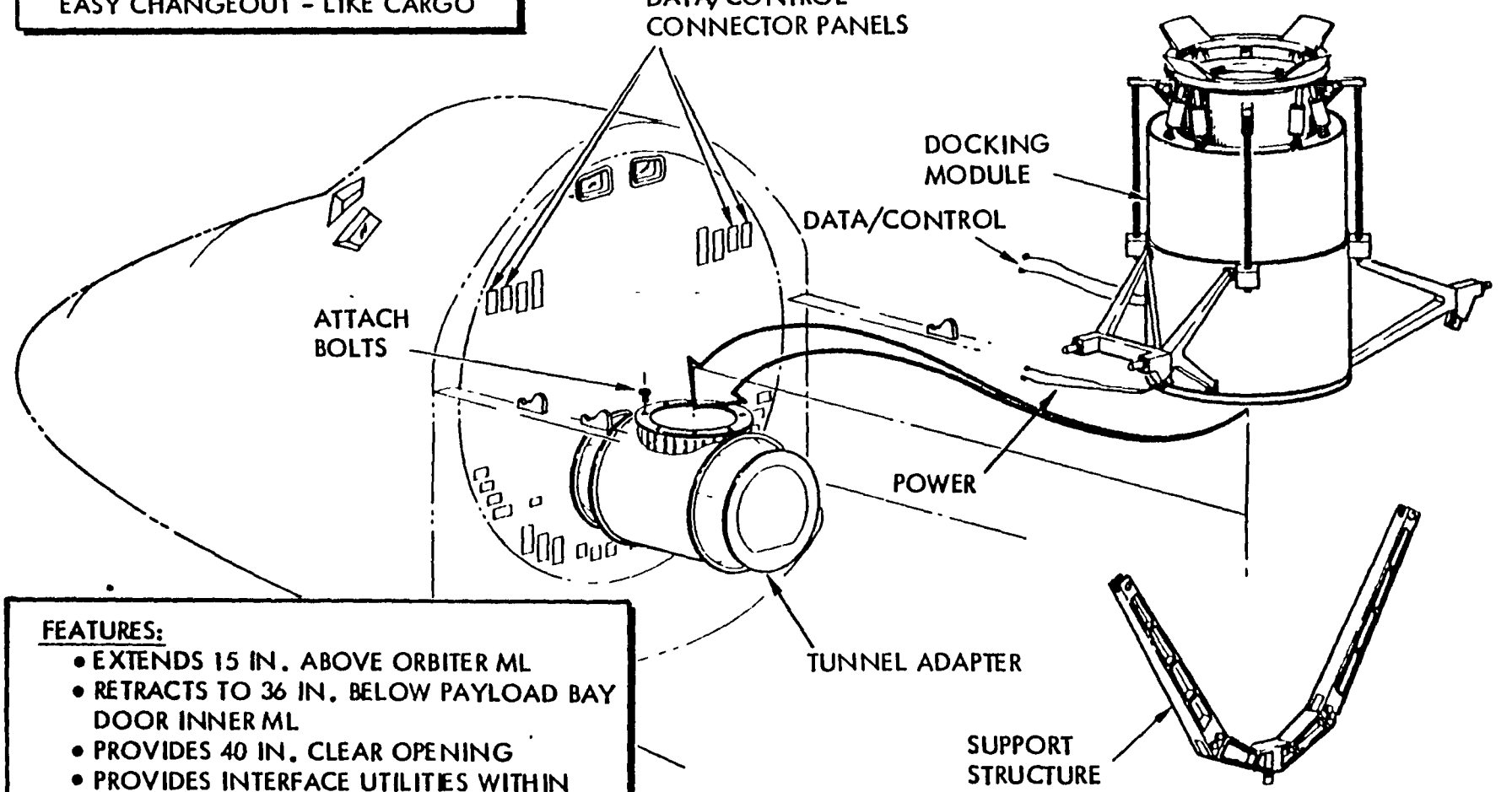


BERTHING ANALYSIS CONCLUSIONS

- RMS BERTHING APPEARS FEASIBLE
  - STOPPING DISTANCE & ANGLES WITHIN 18 INCHES & 5 DEGREES
  - HIGH RESIDUAL MOTIONS INVESTIGATED
  - NO DANGER OF CONTACT
- MINOR SOFTWARE MODS REQUIRED
  - CAN ARREST RESIDUAL MOTION W/CURRENT SOFTWARE
  - CANNOT MANEUVER & STABILIZE TO MATE BERTHING PORTS
- FURTHER SIM ANALYSIS REQUIRED
  - CHECK SOC/ORBITER BODY FLEXIBILITY EFFECTS
  - EXPLORE CONTROL GAINS FOR AUTO POSITIONING MODE

DOCKING MODULE CONCEPT

DOCKING MODULE IS DESIGNED FOR EASY CHANGEOUT - LIKE CARGO

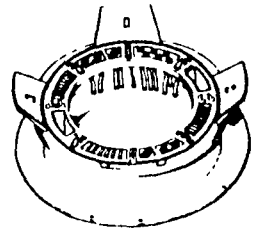


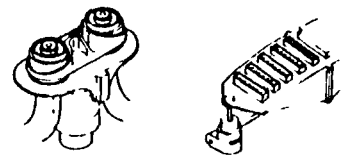
FEATURES:

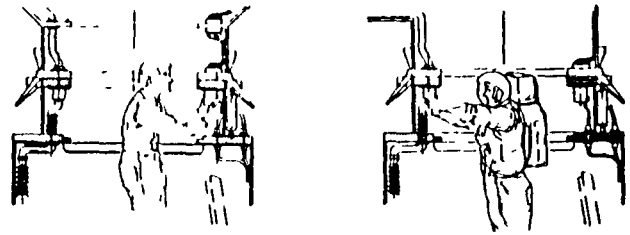
- EXTENDS 15 IN. ABOVE ORBITER ML
- RETRACTS TO 36 IN. BELOW PAYLOAD BAY DOOR INNER ML
- PROVIDES 40 IN. CLEAR OPENING
- PROVIDES INTERFACE UTILITIES WITHIN PRESSURE VOLUME
- PROVIDES ACCESS TO UTILITIES

DOCKING MODULE CHARACTERISTICS

- UTILITIES INTERFACES:
  - ADEQUATE AVAILABLE AREA .....
  - REMOTE CONNECTIONS .....
  - SERVICEABLE .....

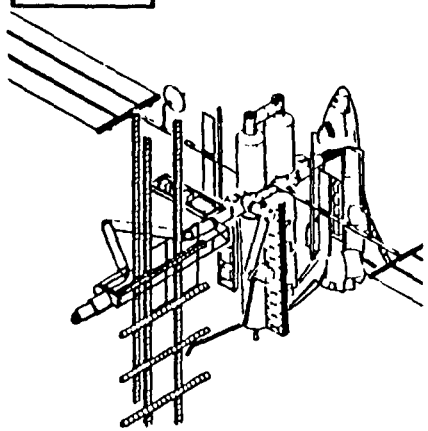




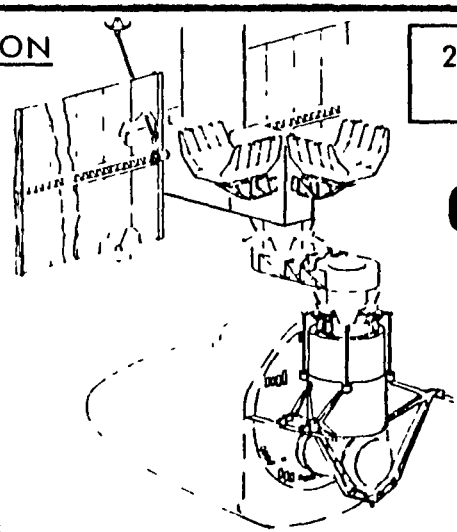


- APPLICATION

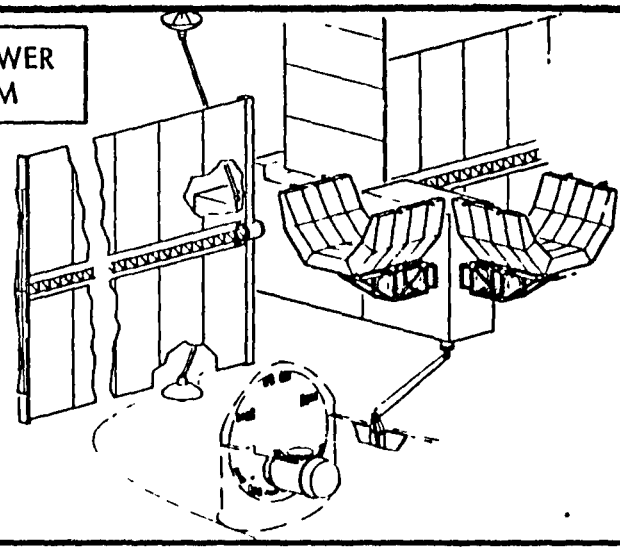
SOC



25 KW POWER SYSTEM



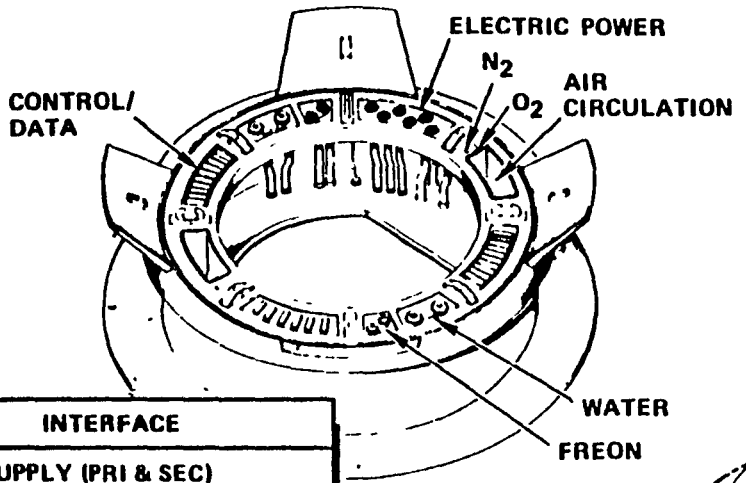
OR



DOCKING/BERTHING INTERFACE CONCEPT

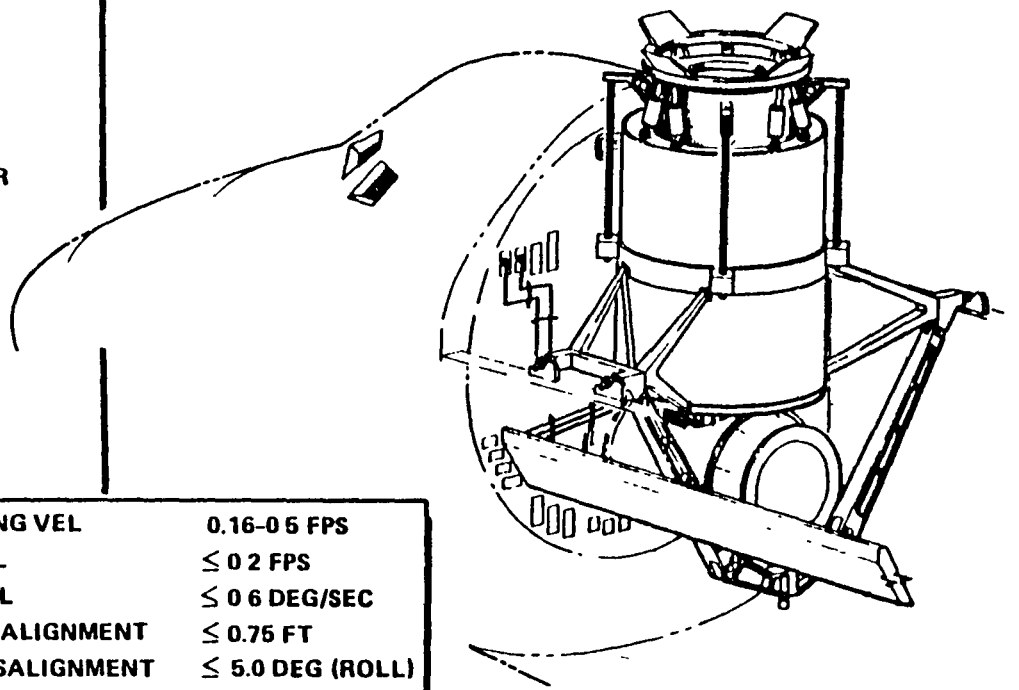
- DEVELOP A STANDARD DOCKING INTERFACE CONCEPT

MODULE INTERFACE



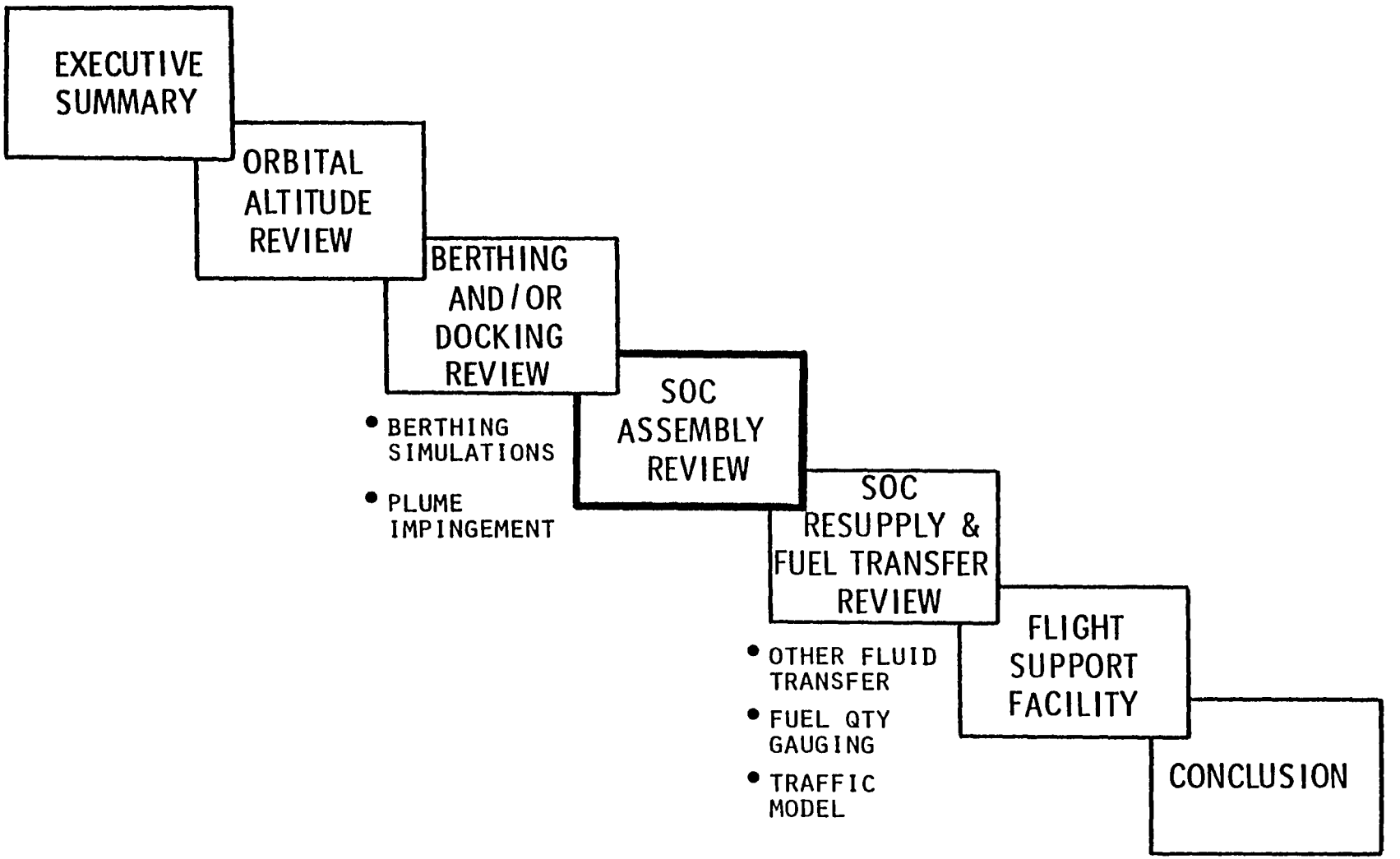
INTERFACE
FREON SUPPLY (PRI & SEC)
FREON RETURN (PRI & SEC)
H_2O COOLANT SUPPLY (PRI & SEC)
H_2O COOLANT RETURN (PRI & SEC)
H_2O COOLANT RETURN (PRI & SEC)
H_2O POTABLE SUPPLY
H_2O WASTE RETURN
O_2 SUPPLY
N_2 SUPPLY
AIR PRESSURE
AIR PROCESSING DUCTS
ELEC. POWER-PRIMARY
ELEC. POWER-SECONDARY
DATA/CONTROL
G/N-RCS
ECLSS
ISS
COMM.-AUDIO/VISUAL
DATA-DIGITAL/ANALOG

ORBITER DOCKING MODULE CONCEPT



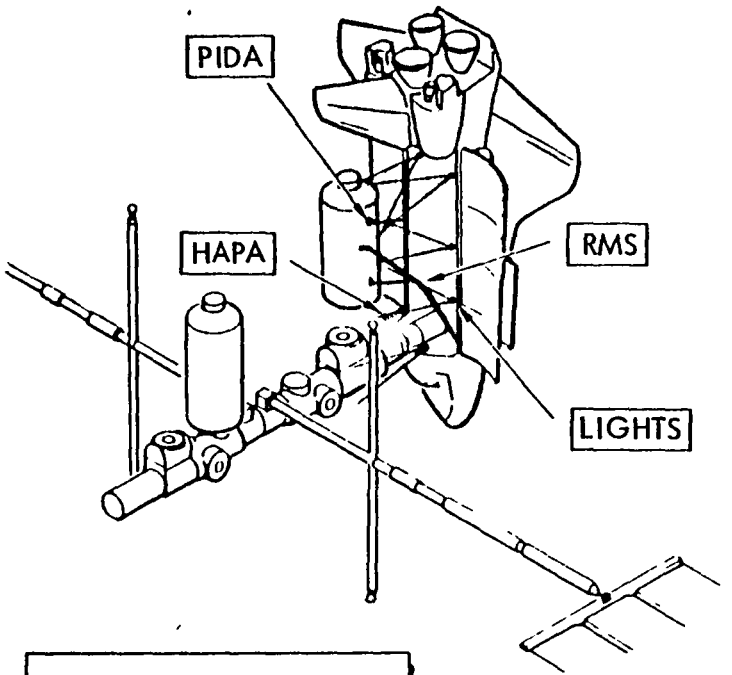
AXIAL CLOSING VEL	0.16-0 5 FPS
LATERAL VEL	≤ 0 2 FPS
ANGULAR VEL	≤ 0 6 DEG/SEC
LATERAL MISALIGNMENT	≤ 0.75 FT
ANGULAR MISALIGNMENT	≤ 5.0 DEG (ROLL)
	≤ 6 0 DEG (PITCH/YAW)

AGENDA

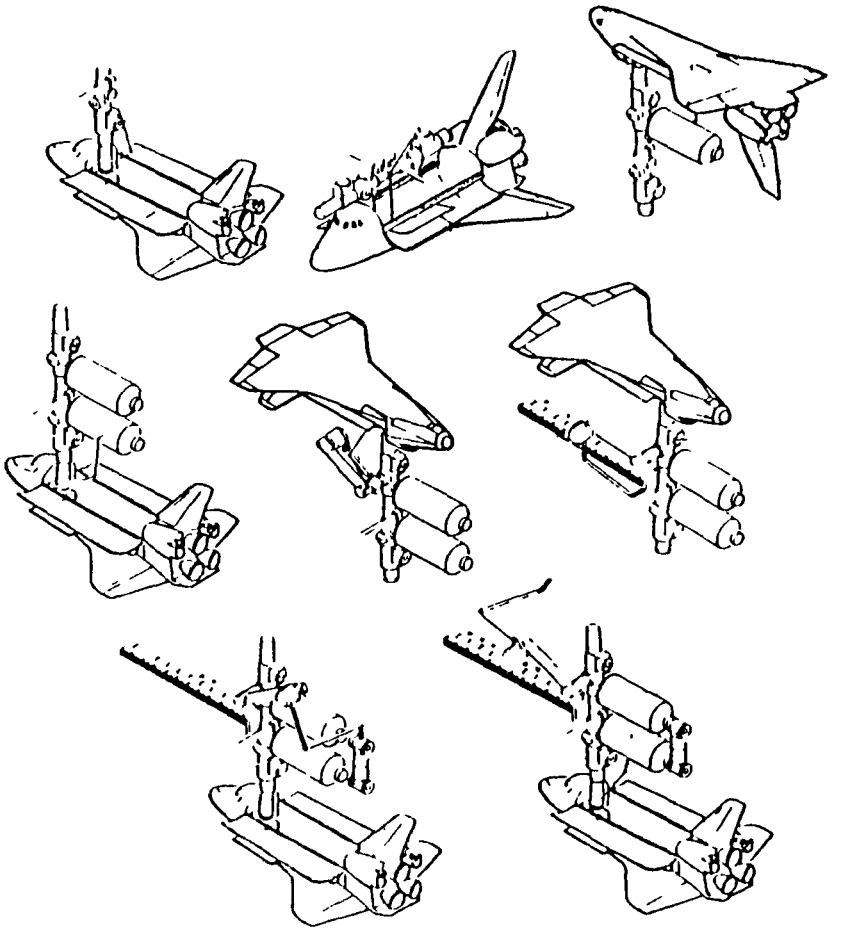

EXECUTIVE SUMMARY
ORBITAL ALTITUDE REVIEW
BERTHING AND/OR DOCKING REVIEW
• BERTHING SIMULATIONS
• PLUME IMPINGEMENT
SOC ASSEMBLY REVIEW
SOC RESUPPLY & FUEL TRANSFER REVIEW
• OTHER FLUID TRANSFER
• FUEL QTY GAUGING
• TRAFFIC MODEL
FLIGHT SUPPORT FACILITY
CONCLUSION

SOC ASSEMBLY

SOC CAN BE ASSEMBLED WITH ORBITER PROVISIONS IN DEVELOPMENT OR PLANNED

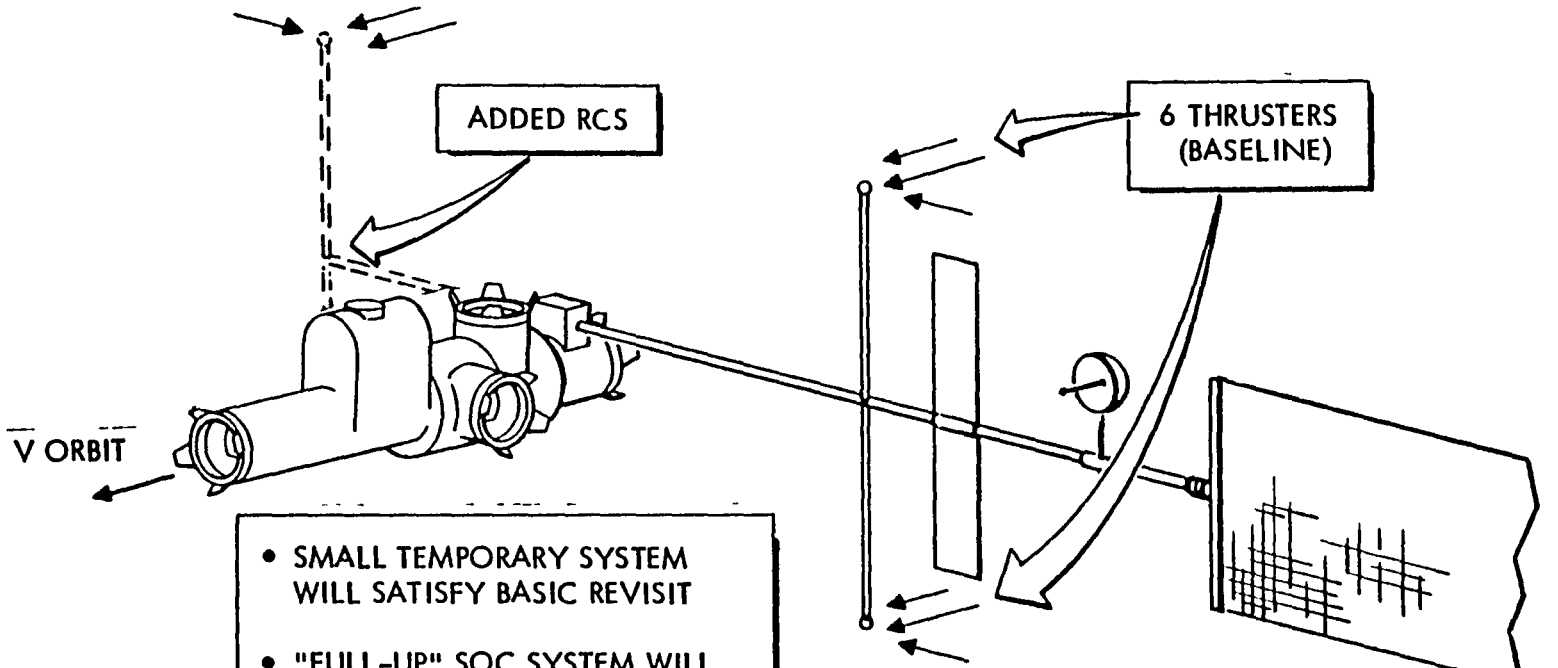


PLUS
SUPPLEMENTAL LIGHTS
& ALIGNMENT AIDS



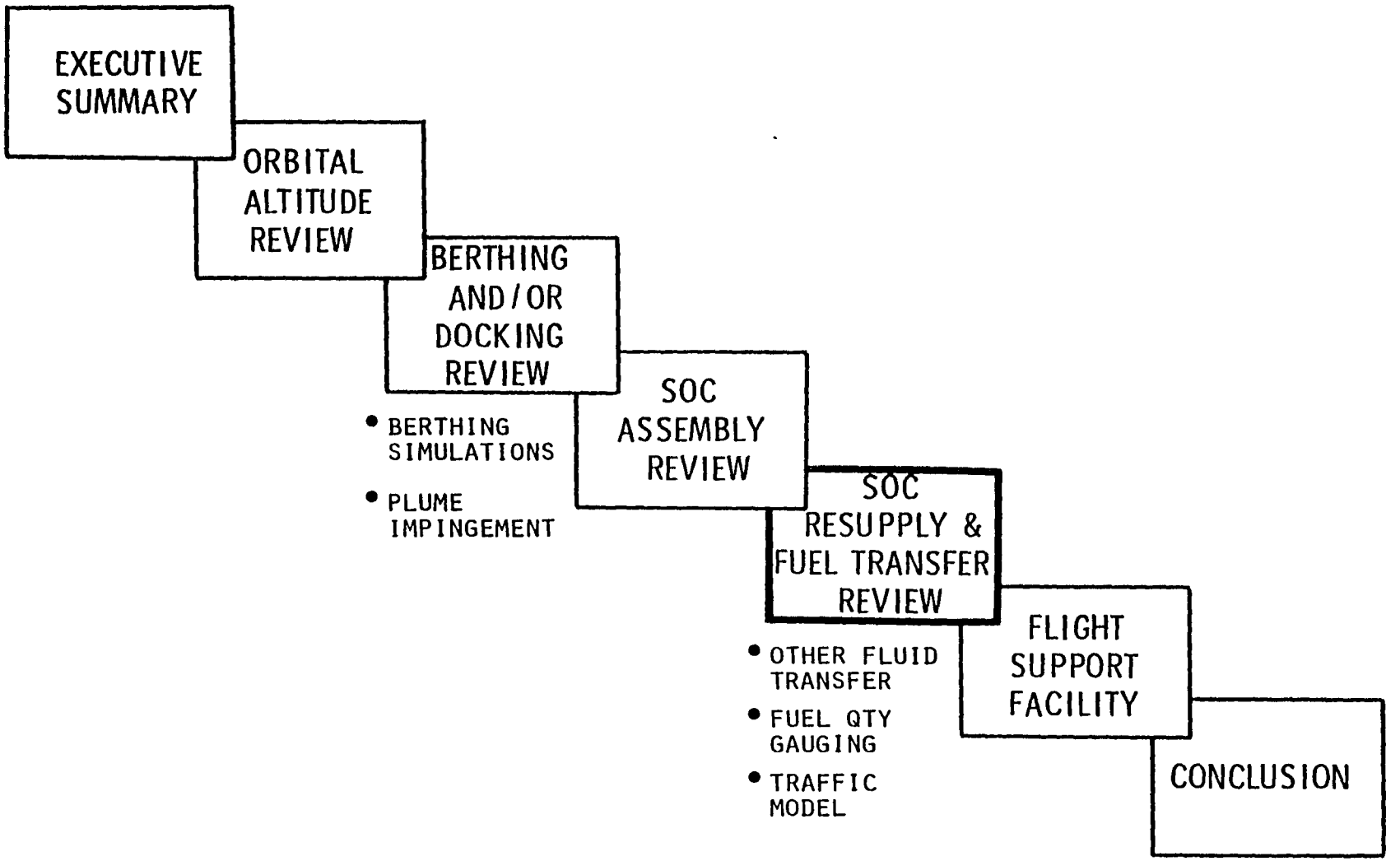
REVISIT STABILITY CONSIDERATIONS

RCS SUPPLEMENT REQUIRED FOR SOC BUILDUP



- SMALL TEMPORARY SYSTEM WILL SATISFY BASIC REVISIT
- "FULL-UP" SOC SYSTEM WILL PROVIDE OPERATIONAL VERSI-TILITY DURING BUILDUP PHASE

AGENDA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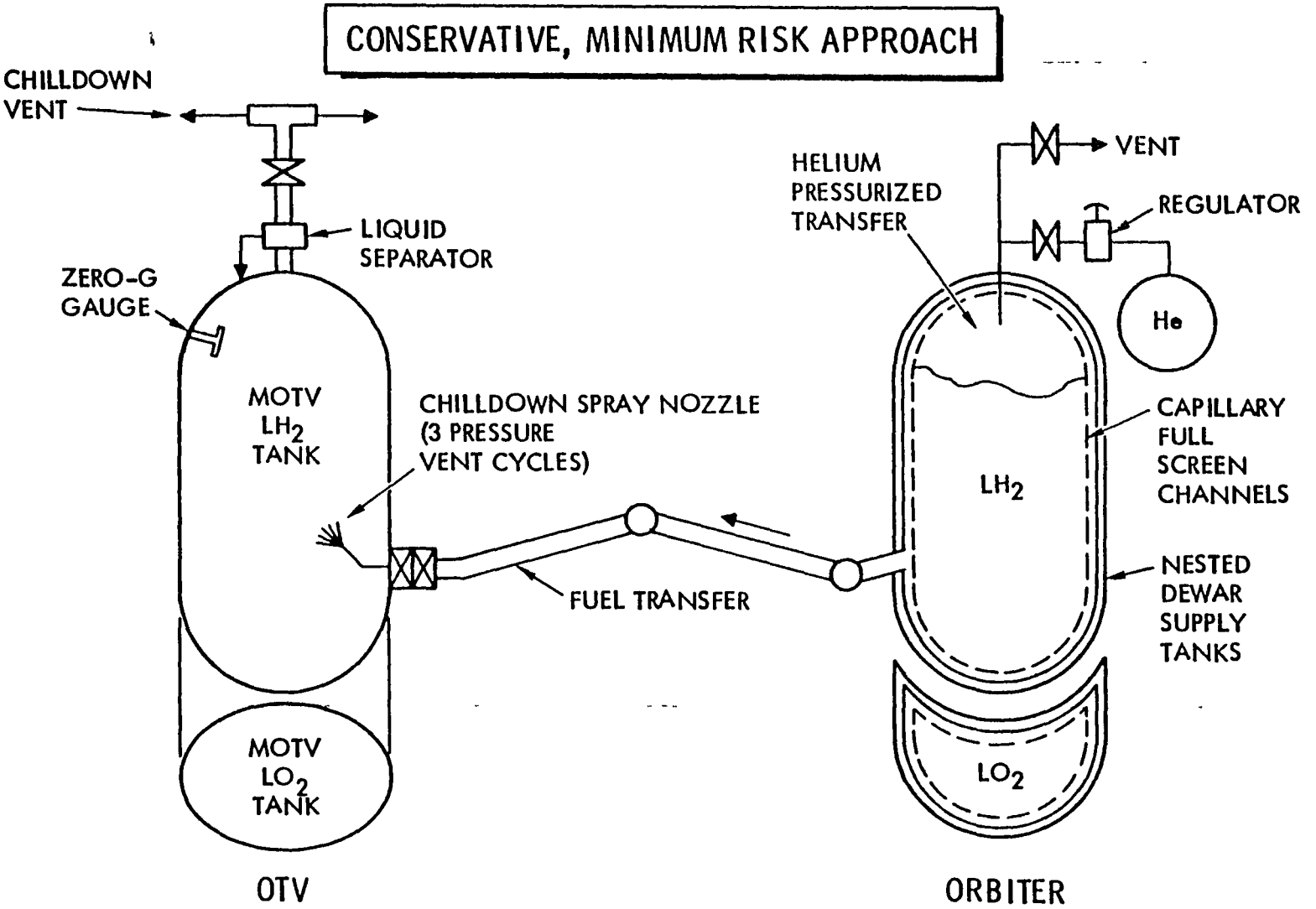
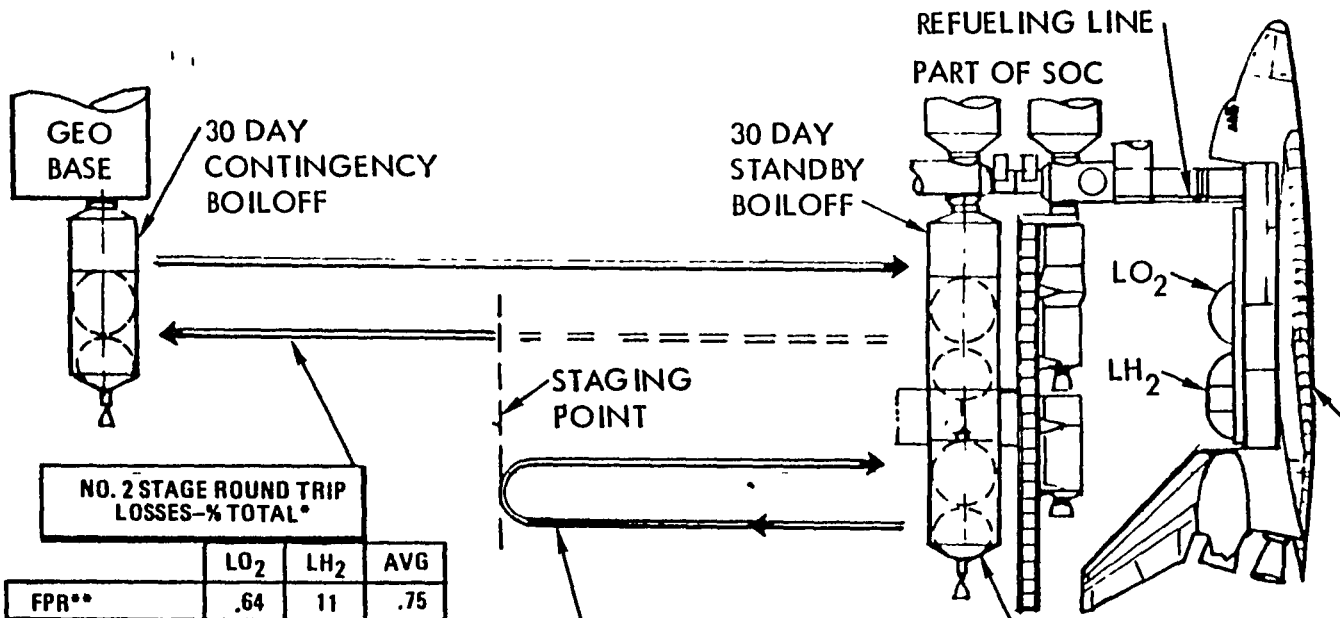
• FUEL QTY GAUGING
• TRAFFIC MODEL
FLIGHT SUPPORT FACILITY
CONCLUSION

SOC-GDC BASELINE REFUEL SCHEMATIC



NOTE: LO_2 TRANSFER SYSTEM SAME AS LH_2 EXCEPT NO CHILLDOWN VENTING

BASELINE CRYO PROPELLANT
LOSS MODEL (MOTV/SOC/ORBITER)



NO. 2 STAGE ROUND TRIP LOSSES–% TOTAL*

	LO_2	LH_2	AVG
FPR**	.64	11	.75
FUEL BIAS	—	.10	.10
BOILOFF	20	20	40
LIQ TRAPPED	.45	05	50
VAP TRAPPED	.17	.13	.30
TOTAL	1 46	.59	2 05

GRAND TOTAL	4.91	2 39	7 3

NO. 1 STAGE ROUND TRIP LOSSES–% TOTAL*

	LO_2	LH_2	AVG
FPR**	64	11	75
FUEL BIAS	—	10	.10
BOILOFF	—	—	--
LIQ TRAPPED	45	.05	.50
VAP TRAPPED	17	13	30
TOTAL	1.26	39	1 65

SOO/MOTV LOSS–% TOTAL*

	LO_2	LH_2	AVG
LINE CHILL	.06	04	.90
MOTV CHILL	—	.30	30
BOILOFF	40	.40	.80
TOTAL	.46	74	1.20

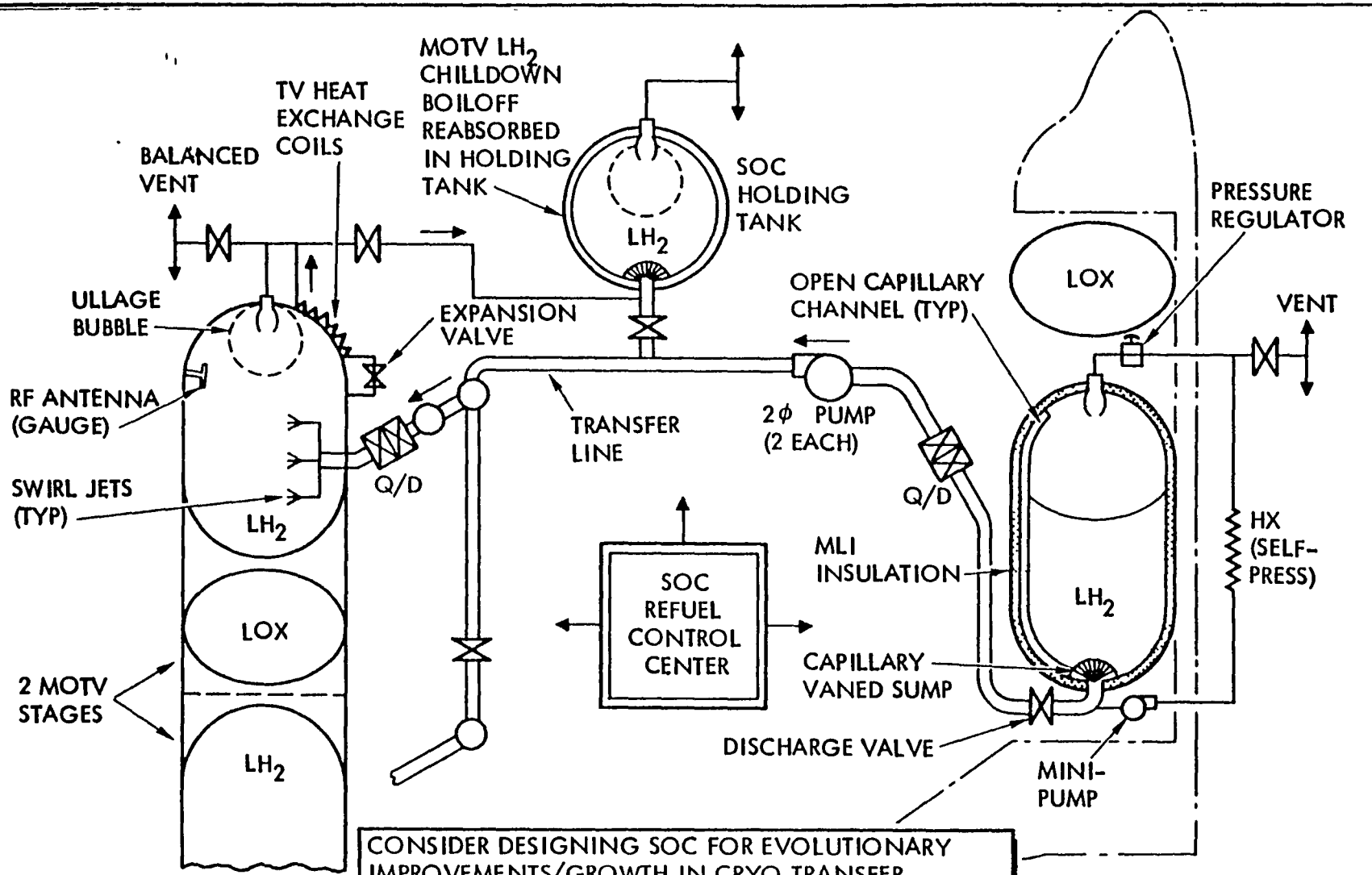
ORBITER LOSS–% TOTAL*

	LO_2	LH_2	AVG
LIQ TRAPPED	1 45	.45	1 9
VAP TRAPPED	.28	.22	.5
TOTAL	1.73	.67	2 4

*% OF TOTAL PROPELLANT LOADED ON GROUND

**FLIGHT PERFORMANCE RESERVE

POTENTIAL PROPELLANT TRANSFER IMPROVEMENTS



CONSIDER DESIGNING SOC FOR EVOLUTIONARY IMPROVEMENTS/GROWTH IN CRYO TRANSFER

- REDUCE FRONT END COSTS
- IMPROVE EFFICIENCY WHEN FLT RATE INCREASES

ET RESIDUALS RECOVERY CONCEPT

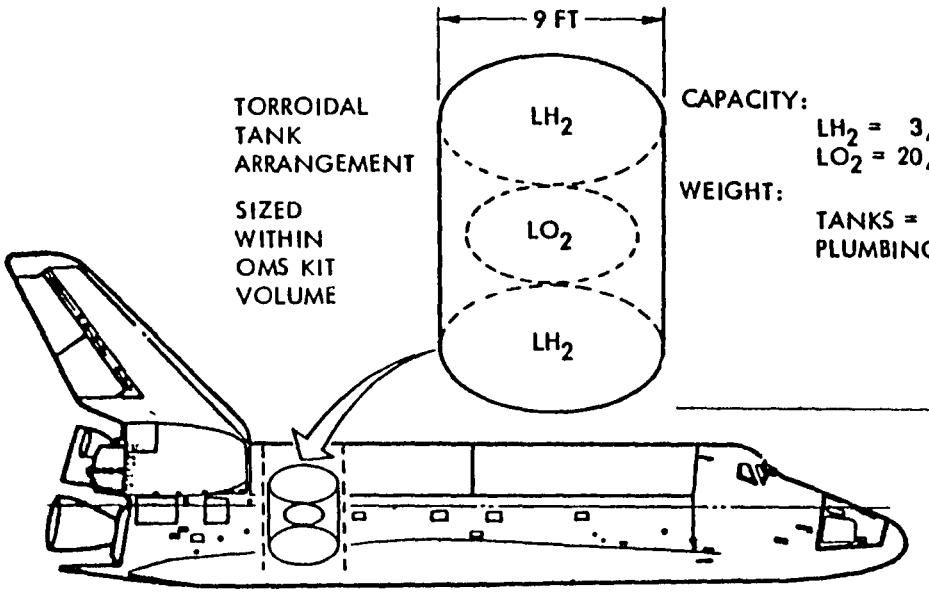
AVAILABLE RESIDUALS - LB

FPR	6000
LH_2	900
ET TRAPPED	850
MPS PLUMBING	1800
TOTAL	9550 (± FPR)

NOTE: UP TO 30,000 LB ADDITIONAL RESIDUALS IF ORBITER UNDERLOADED

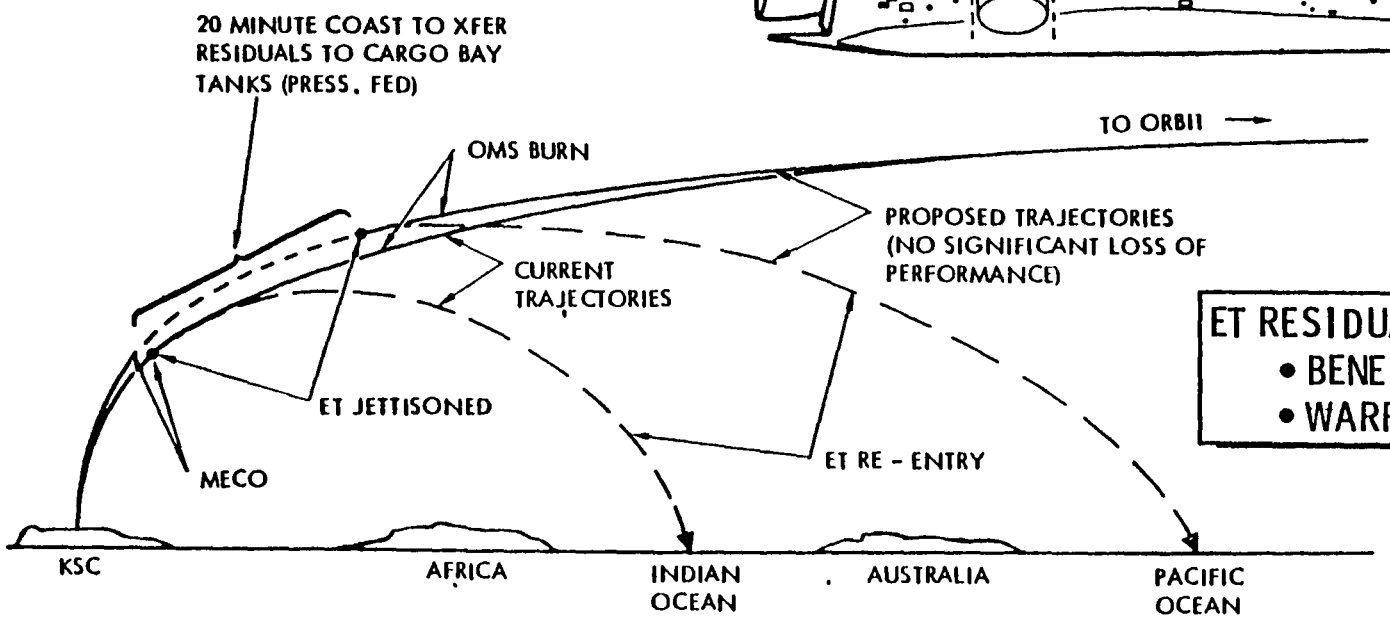
TORROIDAL TANK ARRANGEMENT

SIZED WITHIN OMS KIT VOLUME



CAPACITY:
LH_2 = 3,400 LB
LO_2 = 20,200 LB

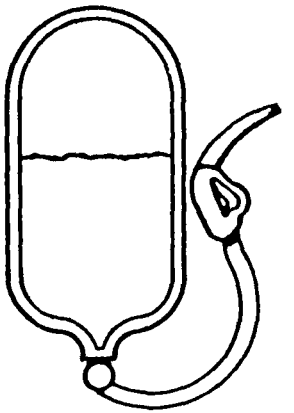
WEIGHT:
TANKS = 800 LB
PLUMBING = 200 LB



ET RESIDUALS RECOVERY
- BENEFITS HIGH
- WARRANTS FURTHER STUDY

SOC BASED CRYO SERVICES

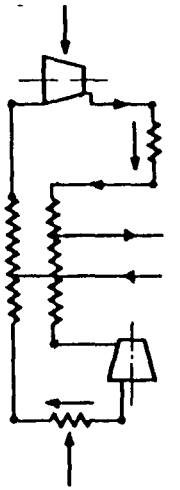
OTV PROPELLANT STORAGE ON SOC IS RECOMMENDED

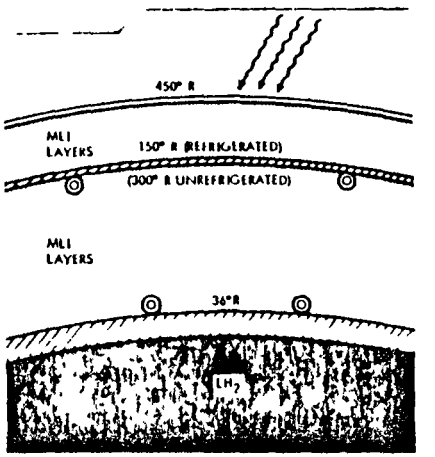


- ALLOWS ET SCAVANGING
- ELIMINATES "ROUND OFF" FLIGHTS
- YIELDS UNCOUPLED LOGISTICS OPS
- EASES FLEET MANAGEMENT
- IMPROVES SHUTTLE UTILIZATION
  - KEEP SHUTTLE FULL
- PROVIDES RAPID MISSION RESPONSE CAPABILITY
- WIDENS OTV DESIGN OPTIONS
  - SPACE BASING
  - RESCUE

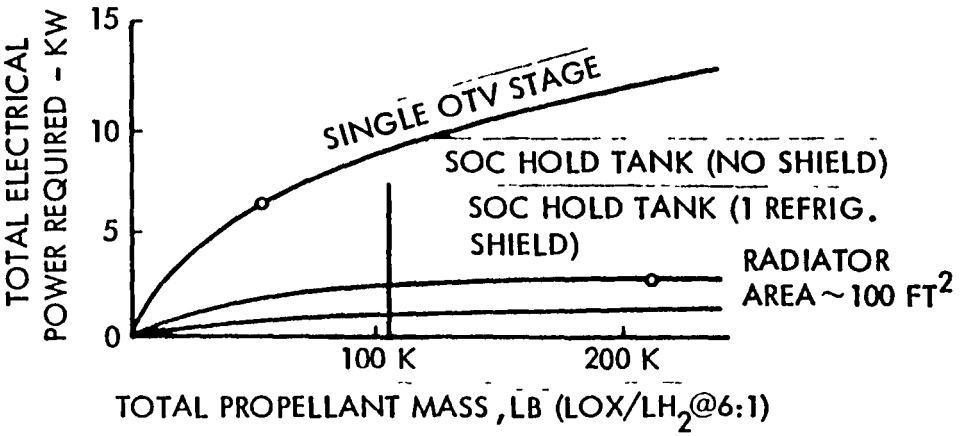
REFRIGERATION IS FEASIBLE

BRAYTON TURBO REFRIG CONCEPT





REFIG SHIELD CONCEPT

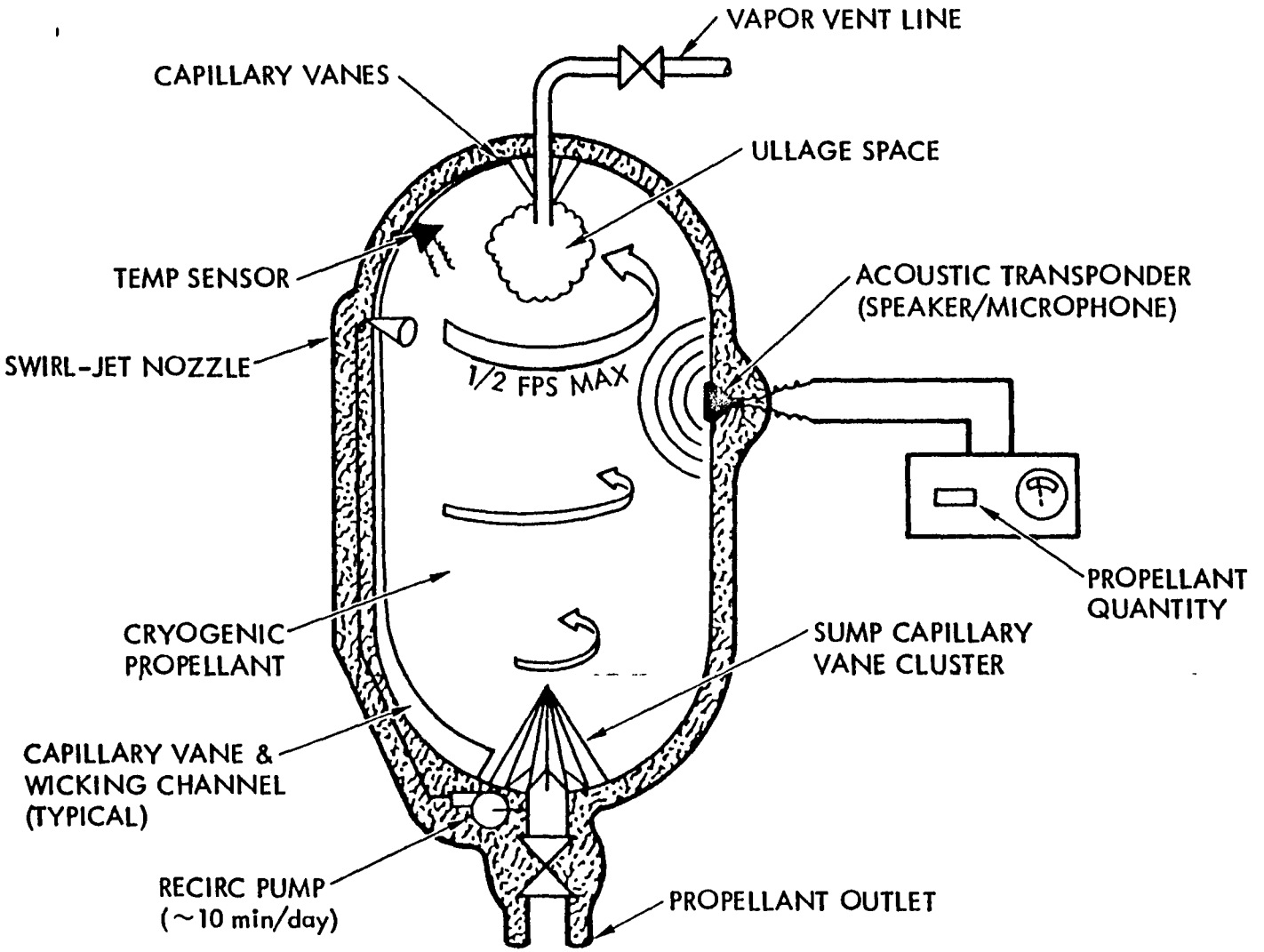


PROPELLANT GAGING CONCEPT SELECTION

CONCEPT	ACCURACY 1-G (FULL/EMPTY)	ACCURACY 0-G (FULL/EMPTY)	RELIABILITY	DEVELOPMENT STATUS	DEVELOPMENT RISK	SAFETY	MISSION OPERATIONS	FLUID COMPATIBILITY	RATING (0-10)
PVT	0.5/3.0	0.5/3.0	GOOD	OPERATIONAL	LOW	EXCELLENT	POOR	NO CRYO	N/A
NUCLEAR	1.0/2.0	1.5/3.0	POOR	FIELD DEMO	MODERATE	FAIR	GOOD	OK	2
RF	2.0/2.0	2.0/3.0	GOOD	LAB DEMO	MODERATE	GOOD	GOOD	OK	4
ACOUSTIC RESONANCE	0.5/3.0	0.5/3.0	GOOD	LAB DEMO	LOW	EXCELLENT	GOOD	OK	(7)
ULLAGE COMPLIANCE	0.5/3.0	0.5/3 0	GOOD	LAB DEMO	LOW	EXCELLENT	FAIR	OK	6
CAPACITANCE	0.5/0.5	2.0/3.0	POOR	OPERATIONAL	LOW	GOOD	GOOD	OK	2
FIBER OPTICS (POINT SENSOR)	0.5/0.5	N/A	GOOD	LAB DEMO	LOW	EXCELLENT	GOOD	OK	(7*)

*POINT SENSORS RECOMMENDED FOR OTV FOR ACCURATE GAGING & MIXTURE RATIO CONTROL AT END OF BURN

ZERO-C CRYOGENIC TANK GAUGING AND PROPELLANT POSITIONING SYSTEM

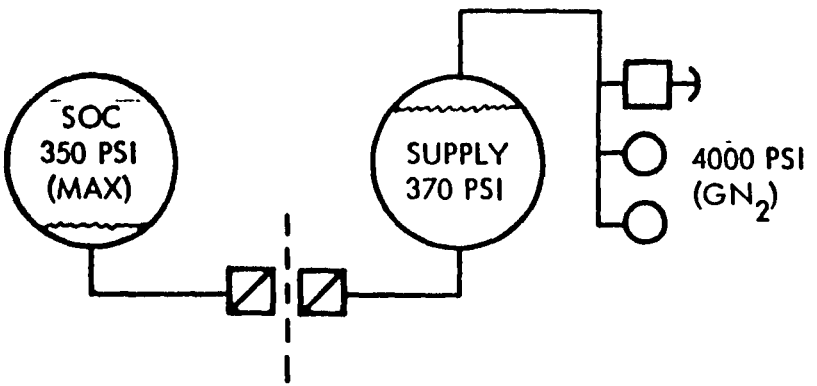


NOTE: GYROSCOPE FORCES NEGLIGIBLE

SOC HYDRAZINE RESUPPLY CONCEPT

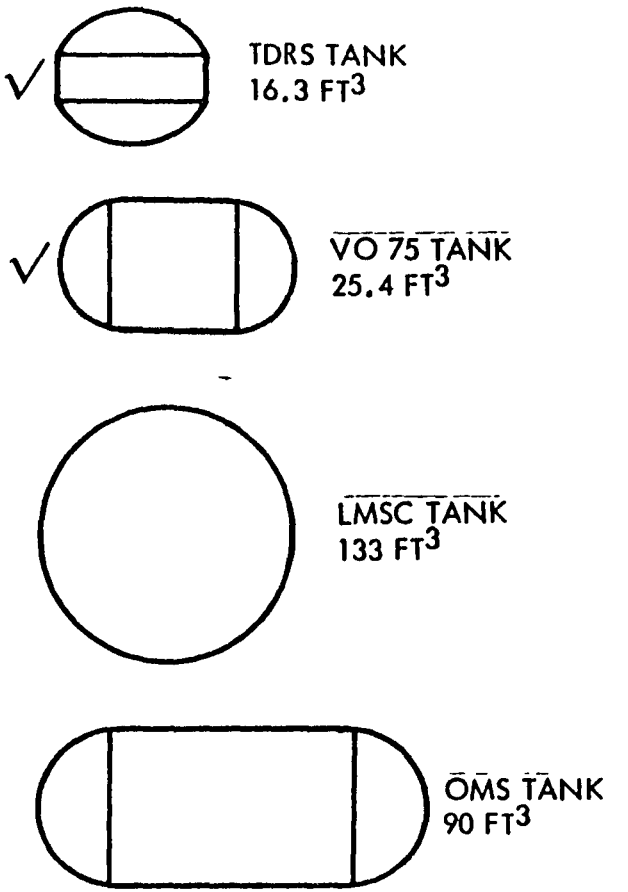
TRANSFER PROCESS

PRESS. XFER	• SINGLE STAGE BLOWDOWN
	• MULTI-STAGE BLOWDOWN
	• REG PRESSURE EXPULSION ✓
PUMP XFER.	• ULLAGE COMPRESSION
	• ULLAGE DISPLACEMENT

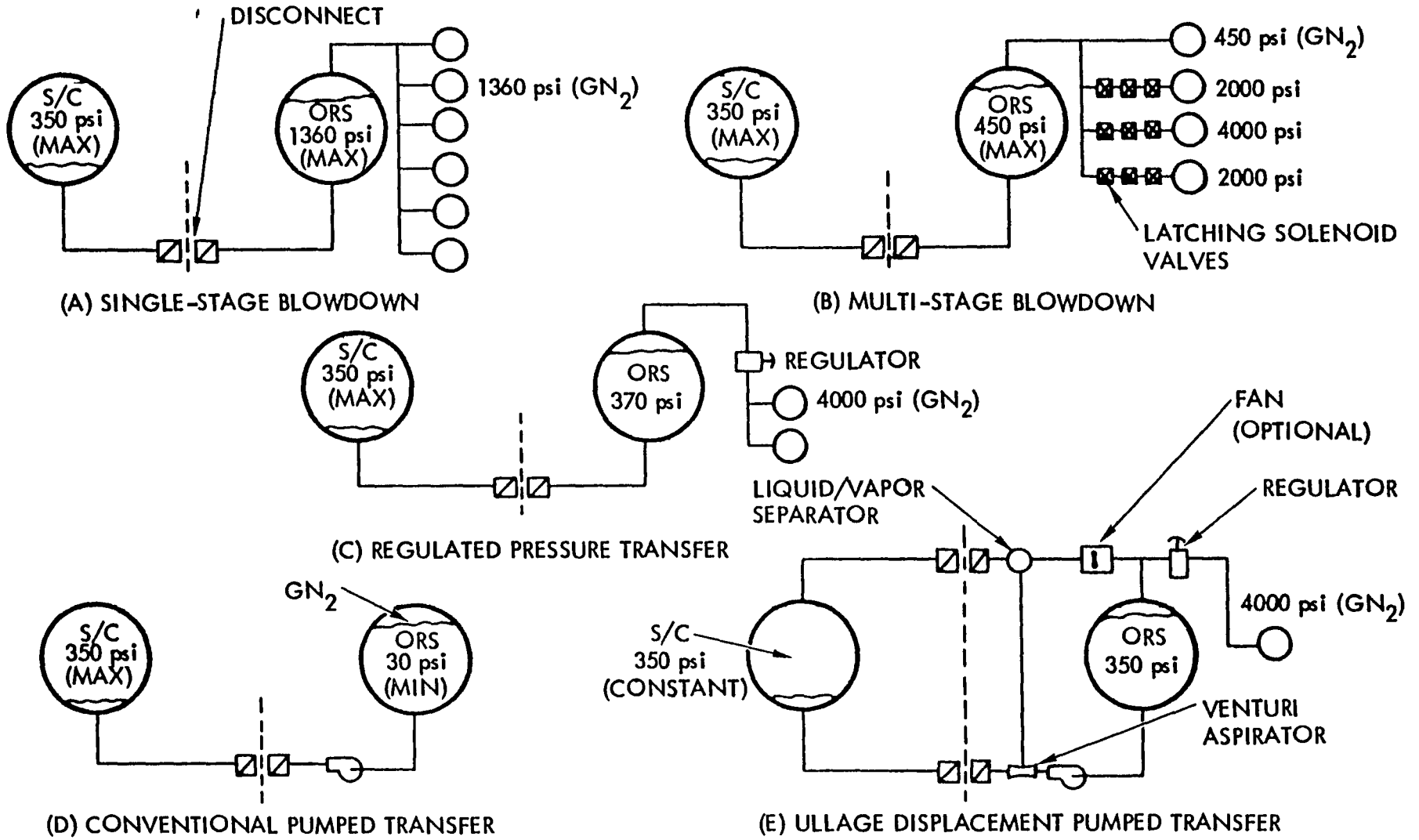


REGULATED TRANSFER CONCEPT

RESUPPLY TANK

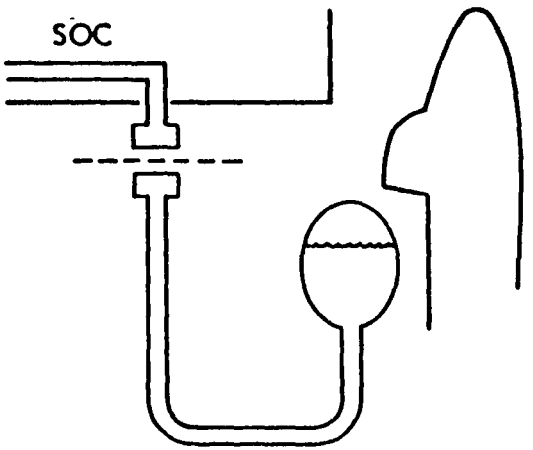


CANDIDATE HYDRAZINE TRANSFER METHODS



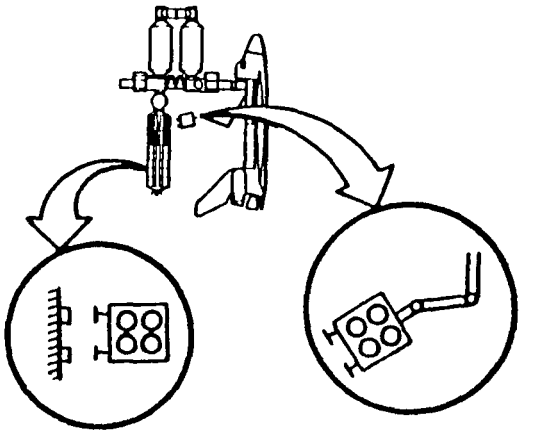
FLIGHT SUPPORT FACILITY FLUID TRANSFER OPTIONS

FLUID TRANSFER



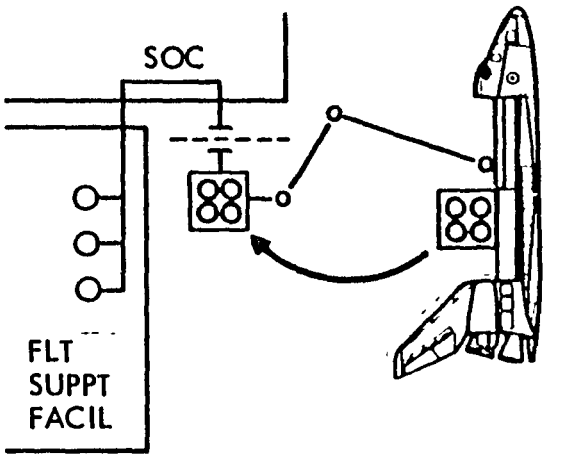
- SIMPLE OPERATIONS
- REQ ADDED LINES & EQUIP ON SOC
- REQ DEDICATED ORBITER BAY INSTALLATION

REPLACEABLE TANK FARM



- ELIM FIXED BAY LOCATION
- COMPLEX OPERATIONS
- POTENTIAL RETURN OF LARGE UNUSED FLUIDS

"HYBRID," TANK FARM WITH FLUID TRANSFER



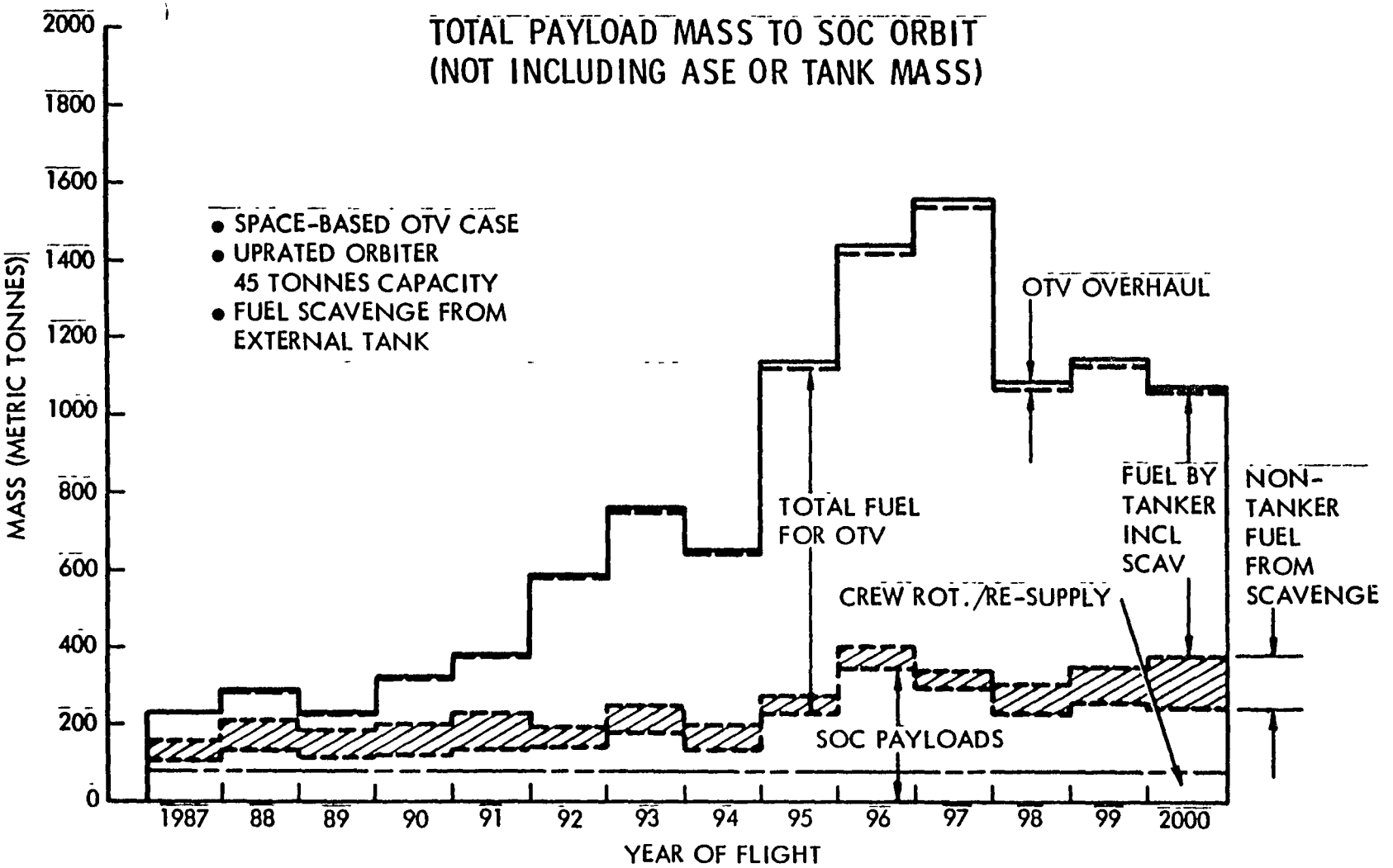
- ELIM BAY INSTALLATION & UNUSED FLUIDS PROBLEM
- REQ ADDED SOC LINES & EQUIP
- OPERATIONAL COMPLEXITY BETWEEN OPTIONS 1 & 2

- PROBABLY ELIM OPTION 1, AVOID MANIFEST CONSTRAINTS
- MORE WORK NEEDED ON FLUIDS USAGE, VARIABILITY, ETC

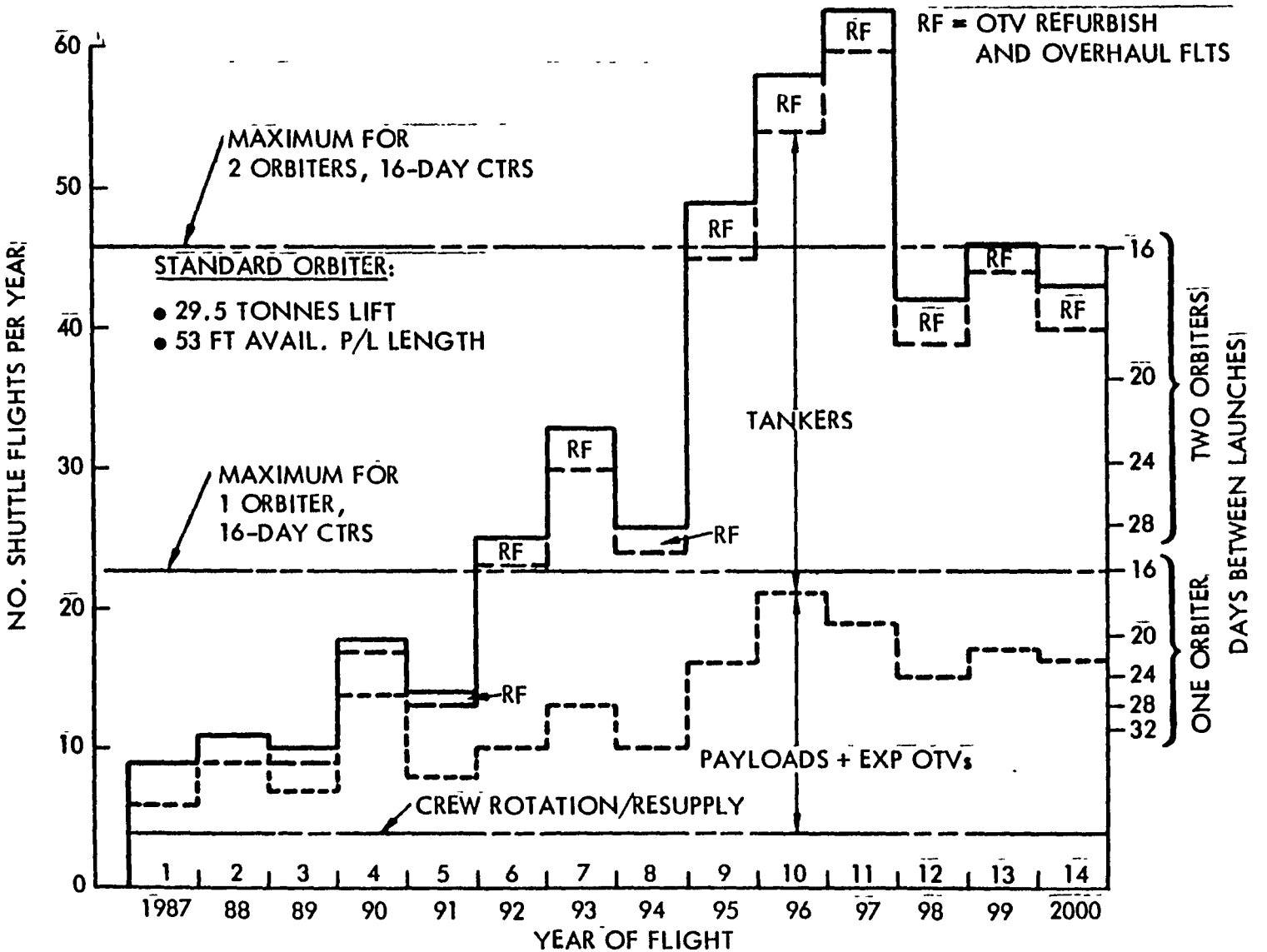
MISSION CHARACTERISTICS, SOC-DESTINED SHUTTLE FLIGHTS

	YEAR OF FLIGHT													
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	NUMBER OF FLIGHTS													
• PLANETARY & LUNAR MISSIONS		1	1		1	1	1	1	2	1	1		1	
• GEOSTATIONARY PLATFORM DEL & SERVICE INCL GEO RADAR	1	1		1	1	3	6	5	8	8	11	7	4	5
• GEOSTATIONARY SPACE STATION (MANNED) DELIVERY & SERVICE MISSIONS										5	4	4	4	5
• DEPT. OF DEFENSE MISSIONS	2	3	4	4	6	5	5	5	2	5	5	4	7	6
• MISC. MULTIPLE PAYLOADS	2	1		2		1		1		1	1	1		1
• DEBRIS REMOVAL (GEO & OTHER ORBITS						1	2	2	5	2	1			
• LARGE, SPECIAL PAYLOADS DELIVERY & DEPLOYMENT						1	2	2	5	2	1			

MASS SUMMARY



TRAFFIC MODEL, SOC-DESTINED ORBITERS
STANDARD SHUTTLE

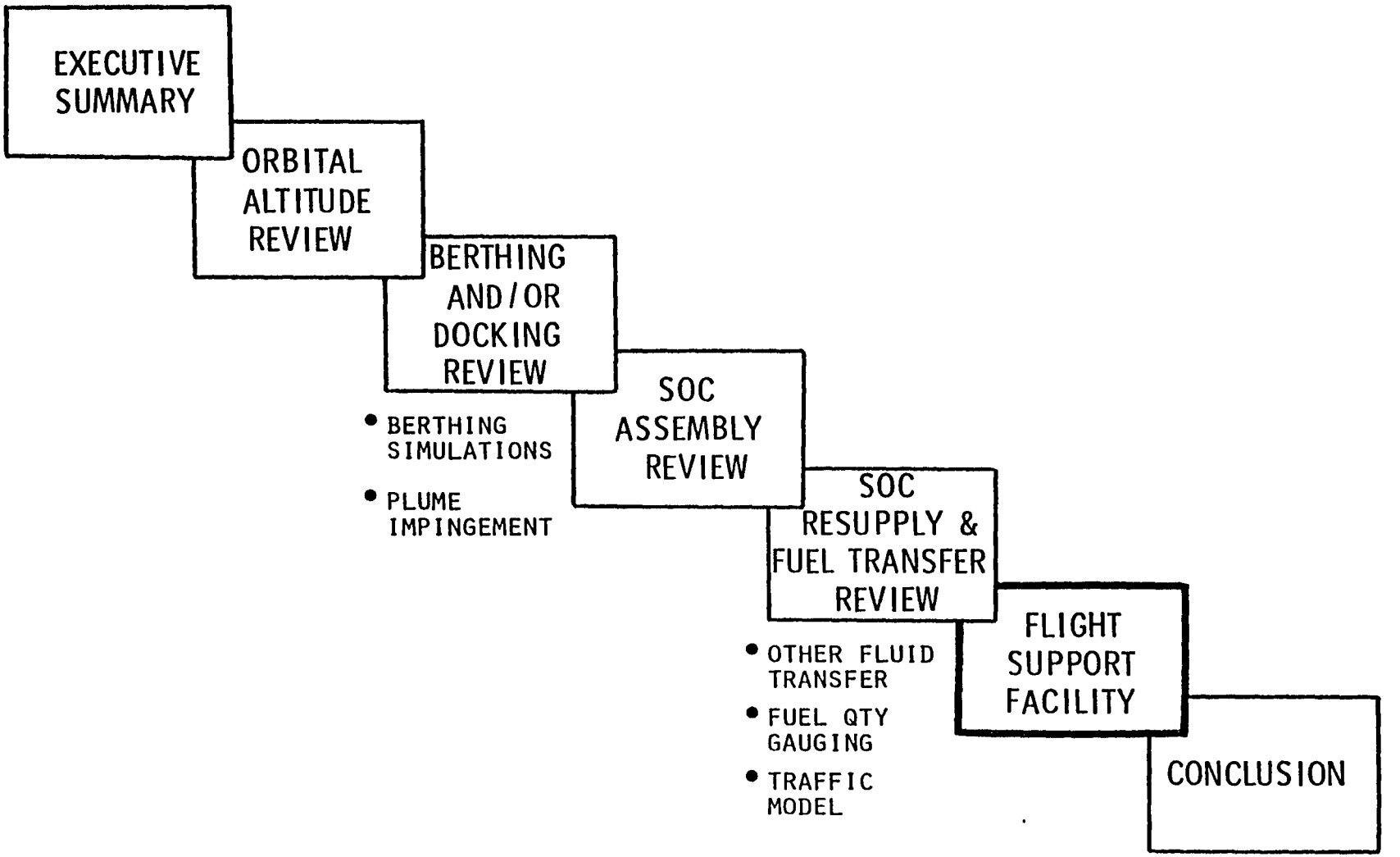


DEDICATED ORBITER EQUIPMENT USAGE

STD EQUIPMENT ITEMS	TYPE OF FLIGHT				WEIGHT (LB)
	SOC RESUPPLY LM	FLIGHT SUPT FACIL LOGISTICS	CONSTR PROJ LOGISTICS	FUEL TANKER	
DOCKING MODULE	X	X	X	X	3900
PIDA (2)	X	X	X		400
HPA (1)	X	X	X		350
SCAVENGE PLUMBING	X	X	X	X	200
SCAVENGE TANK SET	X	X	?	?	800
TANK (TANKER FLTS)				X	7500
RMS	X	X	X		1000
PASSENGER SEATS	X				300
SLEEP STATIONS	*	*	*	*	130
3RD CRYO TANK SET	*	*	*	*	1500
Δ CAMERAS & LIGHTS	X	X	X	X	MINOR WT ITEMS
STD AIRLOCK (REQ DM REV)	*	*	*	*	950
ELECTRICAL HARNESS	*	*	*	*	(TBD)
AFD & CREW HAB EQ	*	*	*	*	(TBD)

*CANDIDATE FOR WEIGHT SAVINGS

AGENDA


EXECUTIVE SUMMARY
ORBITAL ALTITUDE REVIEW
BERTHING AND/OR DOCKING REVIEW
• BERTHING SIMULATIONS
• PLUME IMPINGEMENT
SOC ASSEMBLY REVIEW
SOC RESUPPLY & FUEL TRANSFER REVIEW
• OTHER FLUID TRANSFER
• FUEL QTY GAUGING
• TRAFFIC MODEL
FLIGHT SUPPORT FACILITY
CONCLUSION

TASK 5

FLIGHT SUPPORT FACILITY

TASK 5 OBJECTIVES

- DETERMINE IMPLICATIONS TO SOC FOR SUPPORTING SPACECRAFT ASSOCIATED ACTIVITIES
  - LAUNCH
  - ASSEMBLY
  - SERVICING
  - RECOVERY
- DETERMINE UNIQUE REQUIREMENTS IMPOSED ON SPACECRAFT TO PERMIT THESE SPACE-BASED ACTIVITIES
- DETERMINE IMPLICATIONS ON SHUTTLE FOR SUPPORTING THE SAME ACTIVITIES

DEVELOP FLIGHT SUPPORT FACILITY ARRANGEMENT

APPROACH

- SPACECRAFT SERVICING PHILOSOPHY
- ARRANGEMENT DEVELOPMENT
- IMPLICATIONS
  - SOC
  - SPACECRAFT
  - SHUTTLE

SPACECRAFT SERVICING PHILOSOPHY

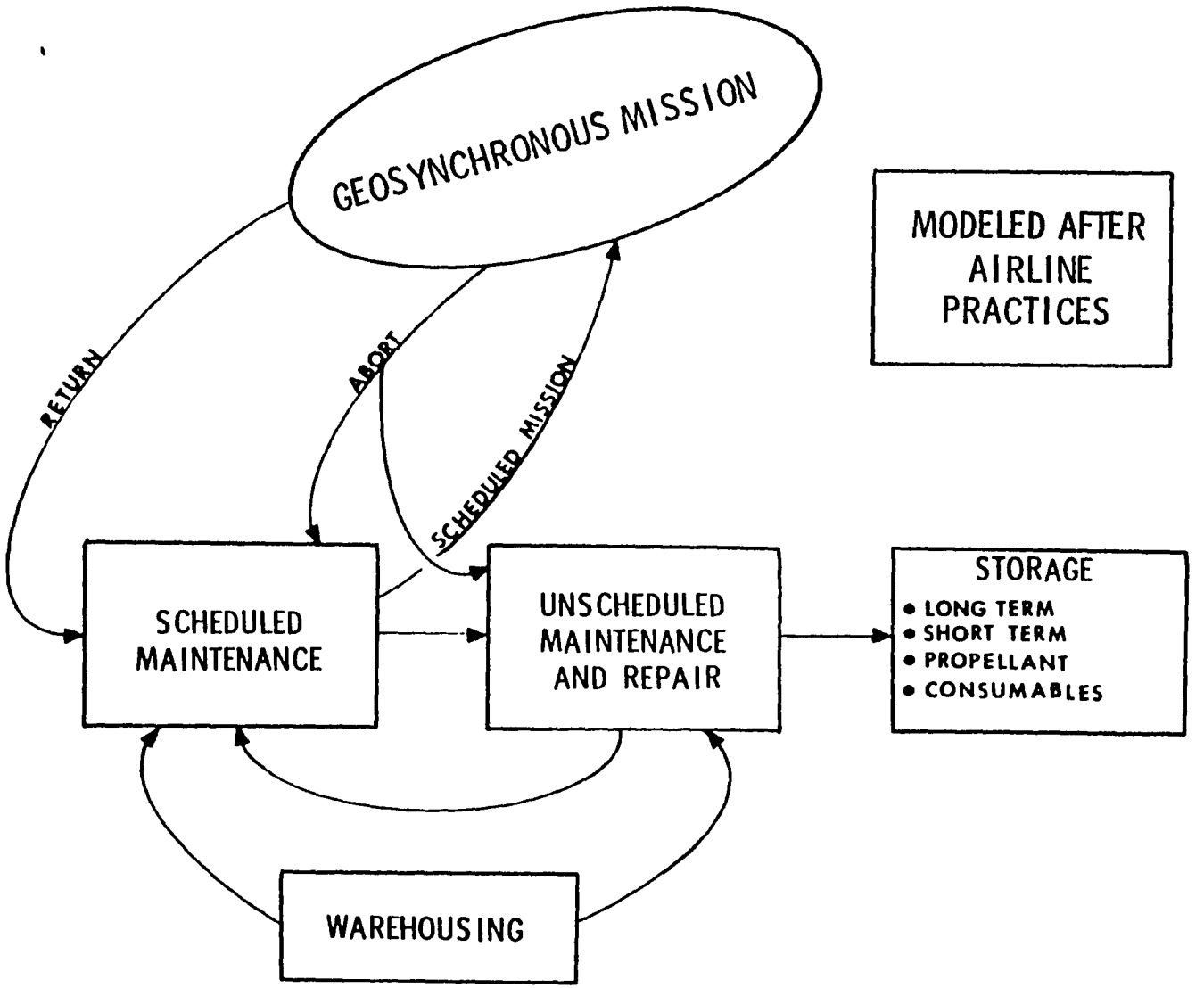
- SPACECRAFT SERVICING ISSUES
- EVA AND/OR REMOTE MANIPULATOR OPERATIONS
- FACILITY GROWTH ISSUES

SPACECRAFT SERVICING ISSUES

DEVELOP VERSATILE MULTIPLE SERVICING FUNCTIONS CAPABILITY

ISSUES	CONSIDERATIONS
• MAINTENANCE/SERVICING	• SCHEDULED MAINTENANCE • UNSCHEDULED MAINTENANCE
• LEVELS OF REPLACEABLE ITEMS	• LRU COMPONENTS • SUBSYSTEM ASSEMBLIES
• WAREHOUSING	• SPARE PARTS, TOOLS, ETC. • SPECIAL EQUIPMENT
• STORAGE (GROWTH CAPABILITY)	• CREW MODULES • OTV ELEMENTS • PROPELLANT
• OPERATIONS	• EVA • MANIPULATOR

SOC MAINTENANCE/SERVICING OPERATIONS CYCLE



EVA AND/OR MANIPULATOR OPERATIONS

- MAN/MACHINE CAPABILITIES
- FUNCTION ALLOCATION CONCERNS
- APPLIED METHODS SELECTION PROCESS FOR LSS CONSTRUCTION
- GUIDELINES FOR MAN/MACHINE FUNCTIONAL ALLOCATION

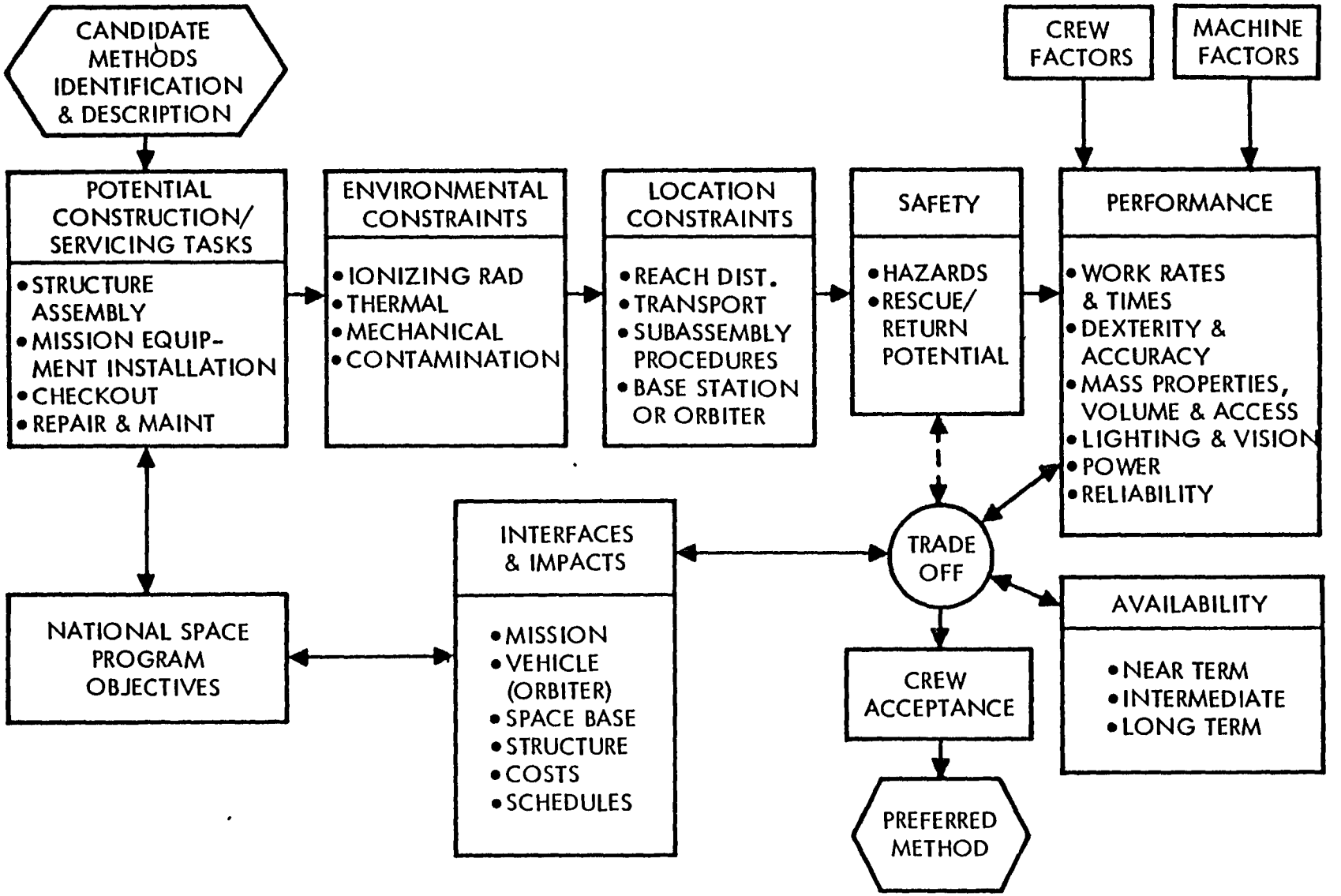
MAN/MACHINE CAPABILITIES

HUMAN SUPERIORITY	MACHINE SUPERIORITY
• ORIGINALITY	• PRECISE, REPETITIVE
• RAPID REPROGRAMMING	• MINIMUM REACTION LAG
• IMPENDING FAILURE RECOGNITION	• DATA STORAGE AND RECALL
• SIGNAL DETECTION	• SENSITIVE TO STIMULI
• OVERLOAD OPERATIONS	• MONITORING FUNCTIONS
• LOGICAL DESCRIPTION OF EVENTS	• EXERTING LARGE AMOUNTS OF FORCE
• INDUCTIVE REASONING	• DEDUCTIVE REASONING
• HANDLING CONTINGENCIES	
• UTILIZING EQUIPMENT BEYOND LIMITS	

ALLOCATION CONSIDERATIONS

- TIME CONSTRAINTS & WORK RATES
- ACCURACY & DEXTERITY
- MASS & SIZE
- REACH & TRAVEL DISTANCES
- PHYSICAL & FUNCTIONAL INTERFACE REQUIREMENTS
- RELIABILITY, SAFETY, & CONTINGENCIES
- ENVIRONMENTAL CONSTRAINTS
- HUMAN & COST FACTORS

METHODS SELECTION PROCESS FOR LSS CONSTRUCTION



EXAMPLES OF GUIDELINES FOR MAN/MACHINE FUNCTIONAL ALLOCATIONS

GUIDELINES	RATIONALE	IMPLEMENTATION
TRANSPORT OF LARGE MASSES		
• USE OF MANIPULATOR EXCEPT FOR COMPLEX AND CRITICAL CLEARANCES	• HIGHER TRANSPORT RATE	• MOBILE MANIPULATOR ON SF RCM RMS
• USE EVA/CHERRY PICKER FOR COMPLEX AND CRITICAL CLEARANCES	• DEPTH PERCEPTION WIDE VISION RANGE MONITORING DURING TRANSPORT	• EVA/CHERRY PICKER MOUNTED ON MANIPULATOR
WORK STATION OPERATIONS		
• USE EVA FOR - DEXTEROUS OPERATIONS - INSPECTION	• DEMONSTRATED CAPABILITY • LOW DEVELOPMENT COST	• EVA/CHERRY PICKER MOUNTED ON MANIPULATOR
• USE MANIPULATOR FOR REMOVAL/REPLACEMENT OF LRU'S	• MINIMIZES EVA • CAN BE DESIGNED FOR REMOTE HANDLING OPERATIONS	• MOBILE MANIPULATORS ON SF FOR OTV

FACILITY GROWTH ISSUES

- SINGLE-STAGE OTV
- MULTI-STAGE OTV
- MANNED OTV
- CREW MODULE STORAGE
- FUEL STORAGE

SERVICING PHILOSOPHY SUMMARY

- MODELED AFTER AIRLINE PRACTICES
  - SCHEDULED & UNSCHEDULED MAINTENANCE SERVICING CAPABILITY
  - REPLACEMENTS ONLY WHEN NECESSARY
- MINIMIZE EVA OPERATIONS
- INCORPORATE WAREHOUSING FACILITIES
- PROVIDE DEDICATED MAINTENANCE POSITIONS
- PERMIT MULTI-SPACECRAFT SERVICING OPERATIONS
- INCLUDE GROWTH PROVISIONS

SERVICING FIXTURE (SF) ARRANGEMENT DEVELOPMENT

- CRITERIA AND REQUIREMENTS
- CONFIGURATION DEVELOPMENT
- ARRANGEMENT DESCRIPTION

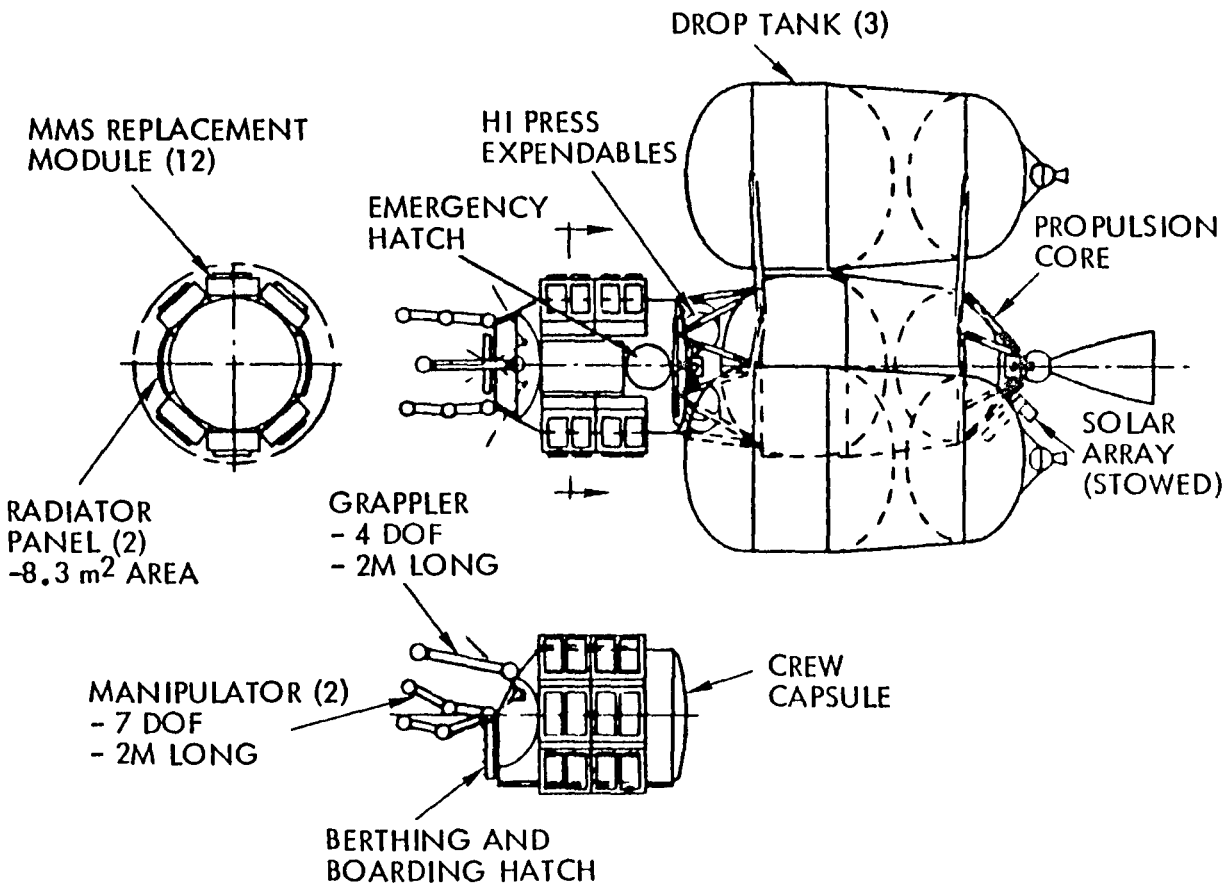
FLIGHT SUPPORT FACILITY ARRANGEMENT CRITERIA

- ACCOMMODATE BOTH TANDEM & PARALLEL TANK / STAGING OTV CONCEPTS
- MINIMIZE CONFIGURATION-INDUCED FORCES ON SOC CONTROL (DRAG, ASSYMETRY, ETC.)
- PROVIDE SERVICING FACILITIES FOR OTVs, PLANETARY VEHICLES, & SATELLITES
- PROVIDE FUEL STORAGE FACILITY (GROWTH)
- PROVIDE SERVICING CONTROL CENTER
- MAINTAIN ORBITER CLEARANCE FOR BOTH A ONE-ORBITER ARRANGEMENT & A TWO-ORBITER ARRANGEMENT
- PROVIDE RCM ACCESS & VISIBILITY TO SERVICING VEHICLES
- PROVIDE DEDICATED PORTS FOR:
  - OTV CREW MODULE
  - LOGISTICS MODULE / CRADLE
  - MOTV

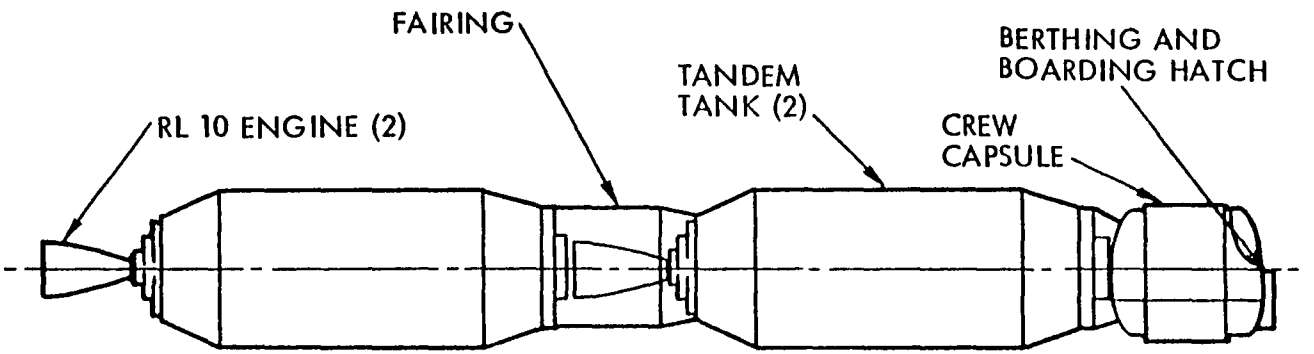
OTV/MOTV MODEL CHARACTERISTICS

- UNMANNED OTV MISSIONS WILL OUTNUMBER MANNED MISSIONS BY 3 TO 1
- SOC STOWAGE PROVISIONS FOR MOTV CREW MODULE
- TWO-PERSON MOTV CREW COMPLEMENT
- NO AIRLOCK IN MOTV CREW MODULE
- MOTV TURNAROUND OPERATIONS WILL INCLUDE AN EVA "WALK-AROUND" INSPECTION
- MOTV/OTV RETURN TO EARTH AFTER 8 MISSIONS FOR MAJOR GROUND OVERHAUL
- MOTV/OTV WILL HAVE SELF-DIAGNOSTIC CAPABILITY WITH BUILT-IN COMPUTER SWITCHING TO REDUNDANT UNITS
- CONSIDER TANDEM AND PARALLEL TANKING/STAGING ARRANGEMENTS FOR SERVICING AT THE SOC

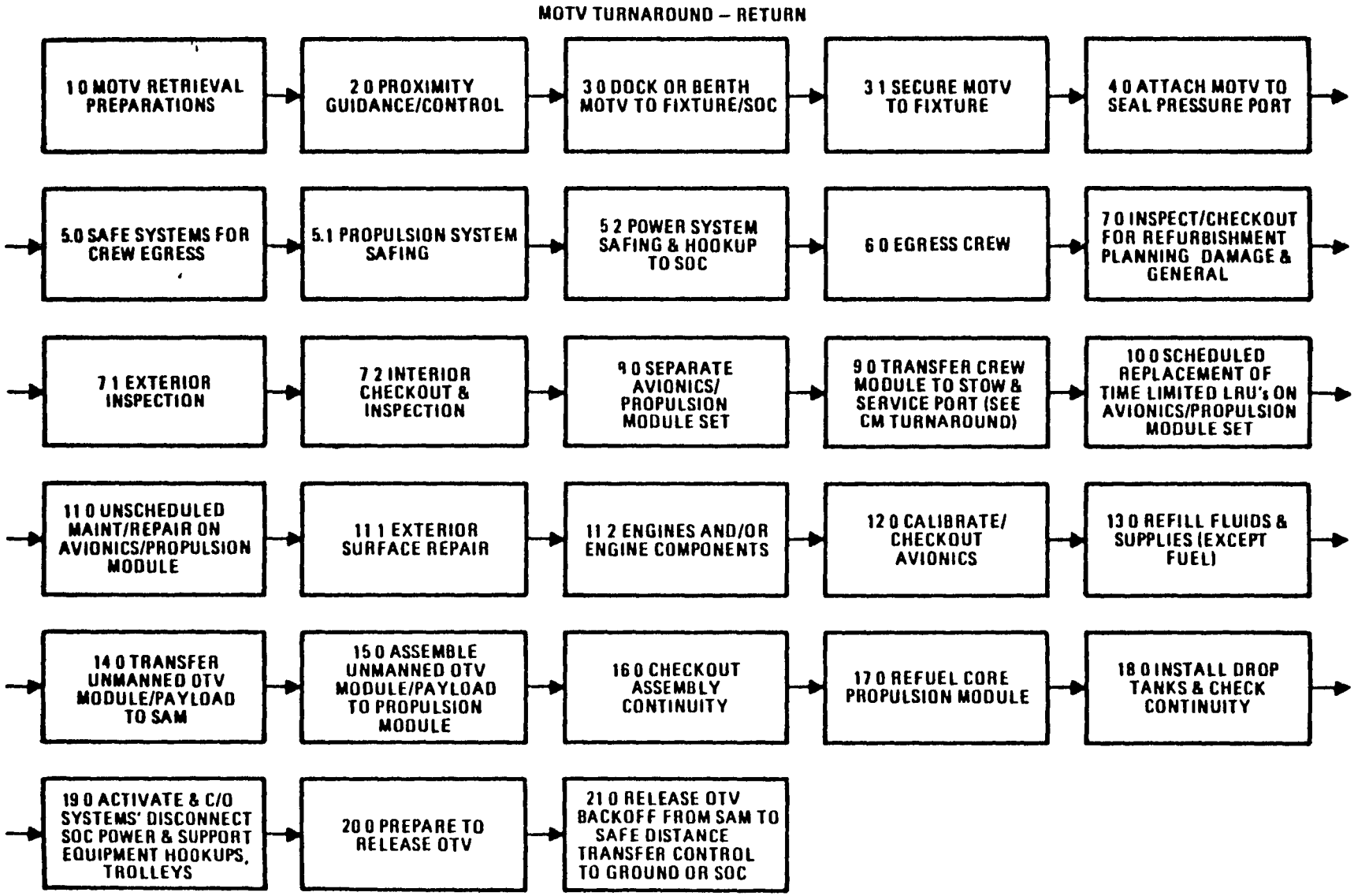
PARALLEL TANKS OTV/MOTV CONFIGURATION



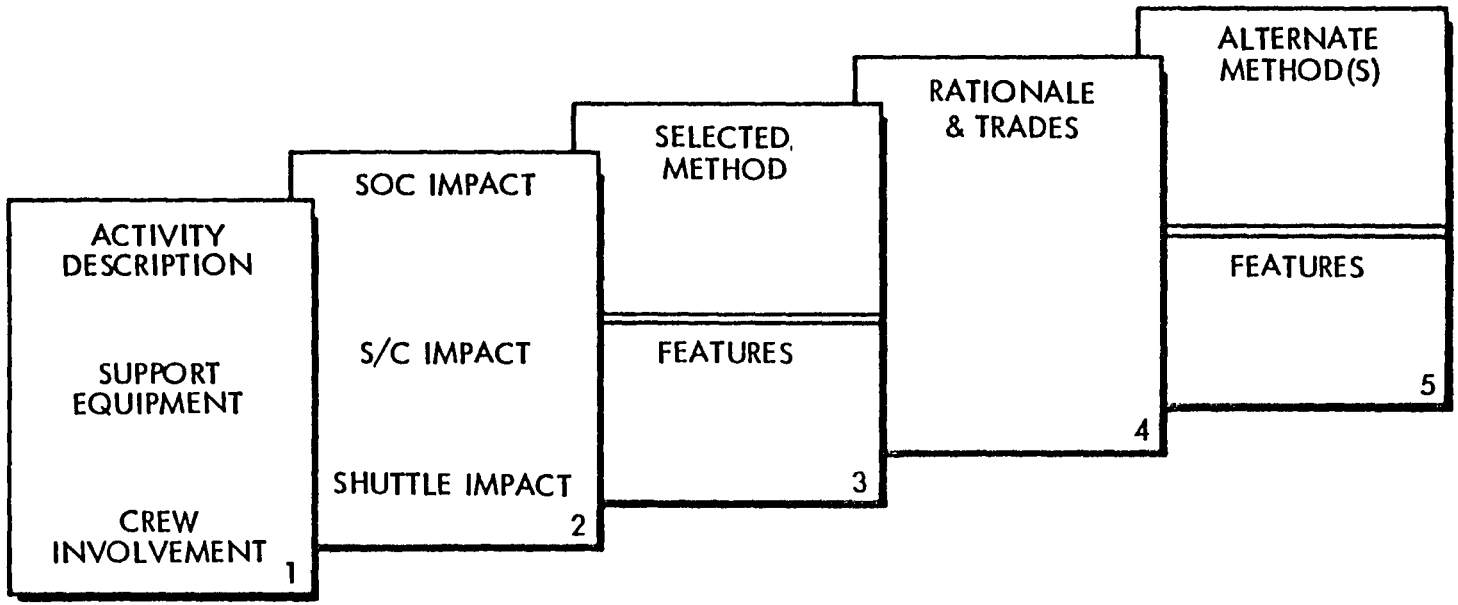
TANDEM TANKS OTV/MOTV CONFIGURATION



MOTV TURNAROUND FLOW CHART



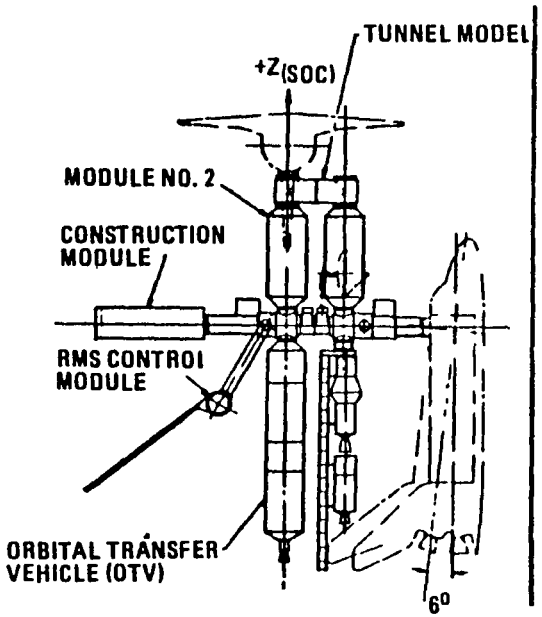
SERVICING ACTIVITY DATA SHEET SCOPE



- PREPARED ONLY FOR CRITICAL FUNCTIONS
- EMPHASIS ON FEATURES SIGNIFICANT TO SERVICING ACTIVITY

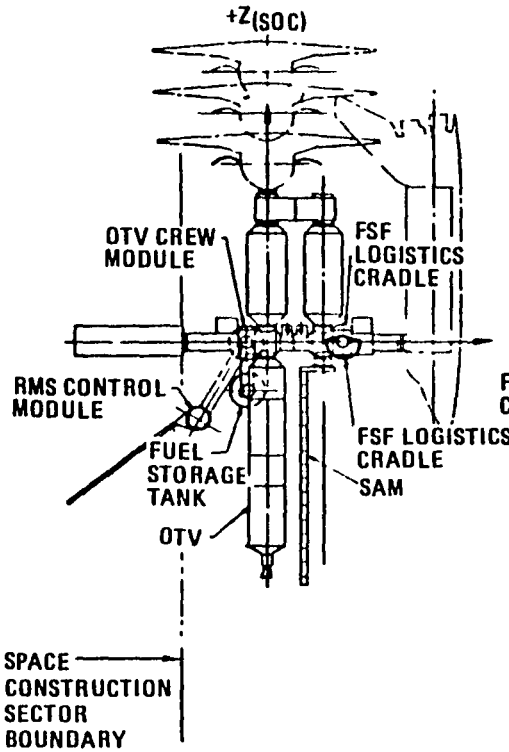
CONFIGURATION DEVELOPMENT

BASELINE



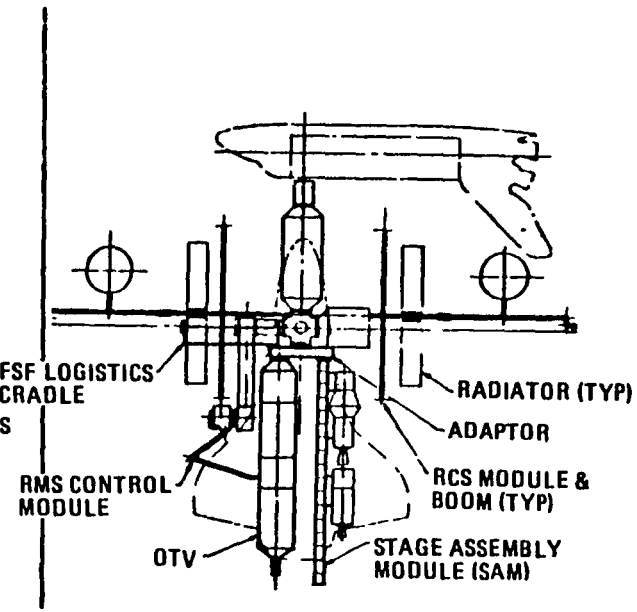
- ORBITER VERTICAL FIN INTERFERENCE

OPTION 1



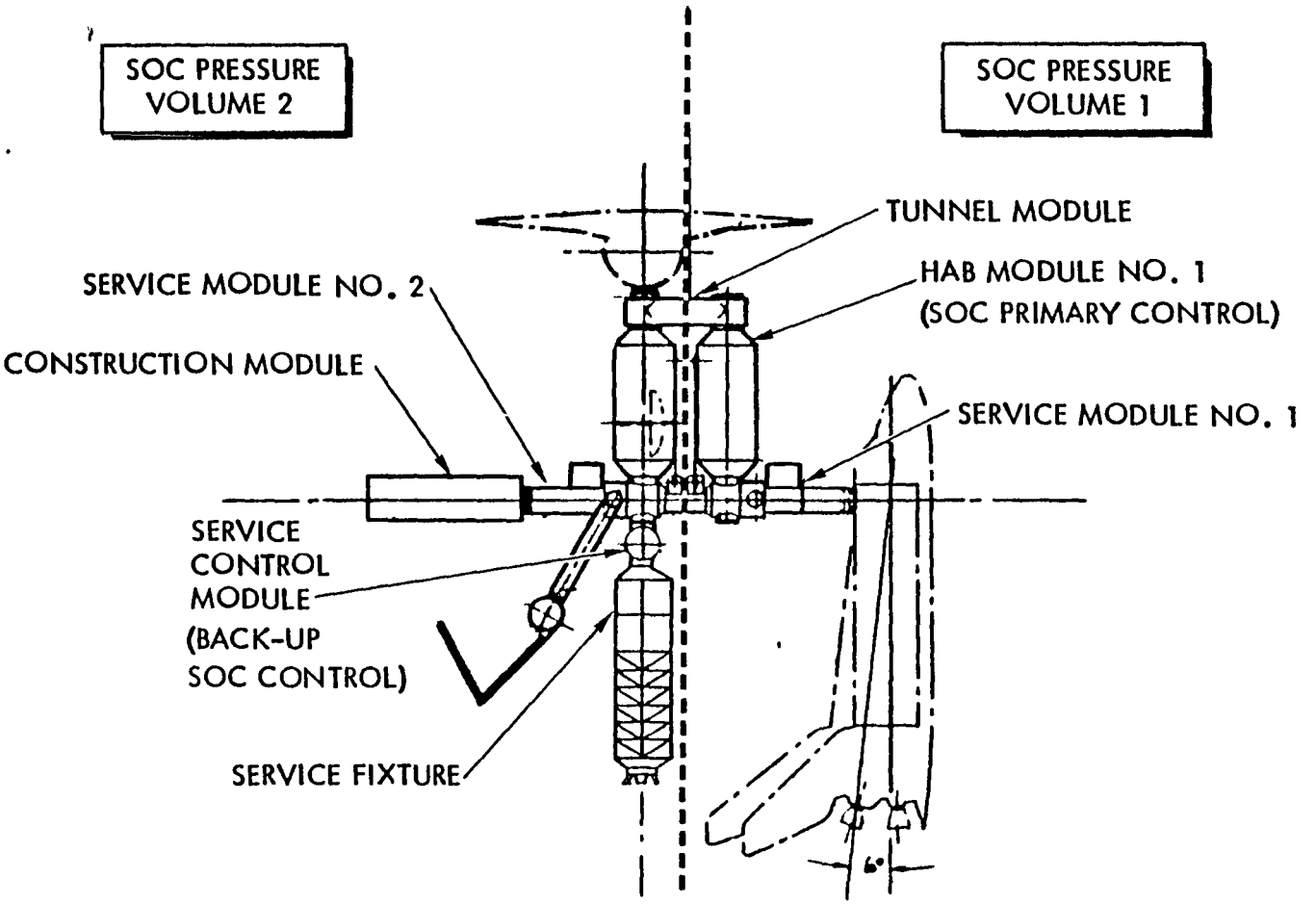
- ORBITER 1 VERTICAL FIN INTERFERENCE WITH ORBITER 2 RADIATOR

OPTION 2



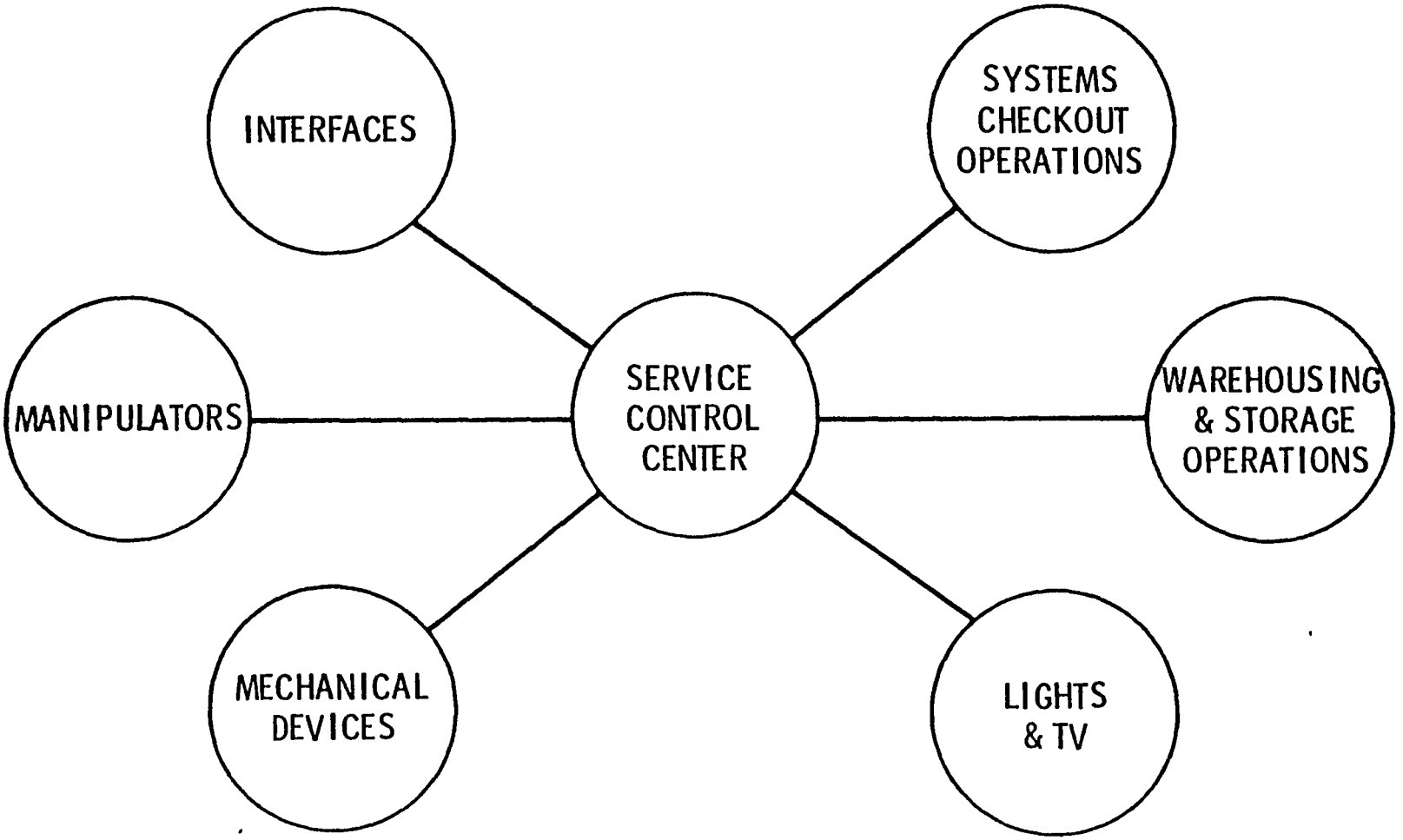
- CLEARANCE BETWEEN ORBITERS
- INCREASED DRAG

SOC PRESSURE VOLUMES



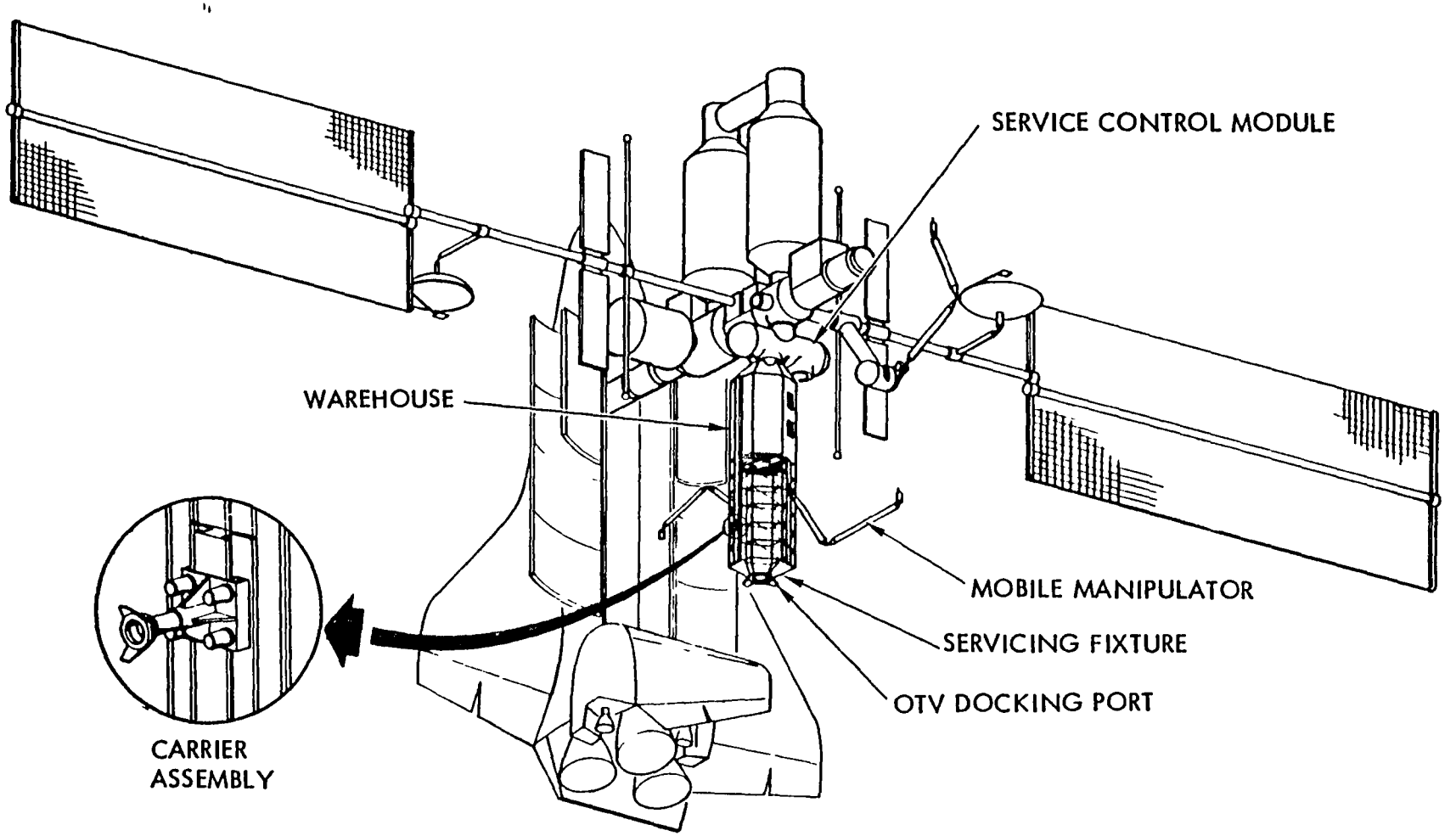
FLIGHT SUPPORT FACILITY CONTROL

- CONTROLS & MONITORS ALL FLIGHT SUPPORT FACILITY FUNCTIONS

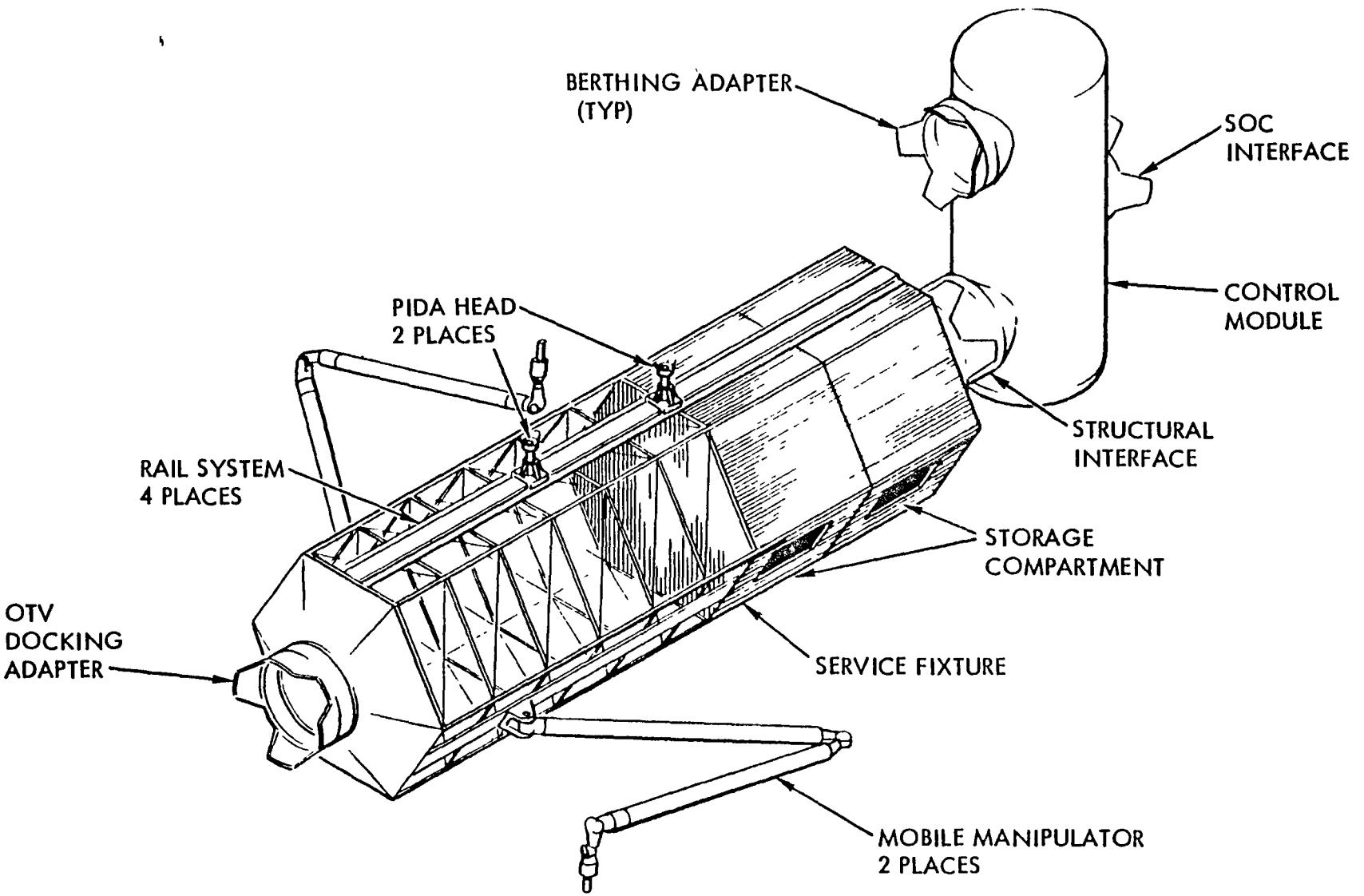


- SERVES AS BACKUP FOR SOC CONTROL

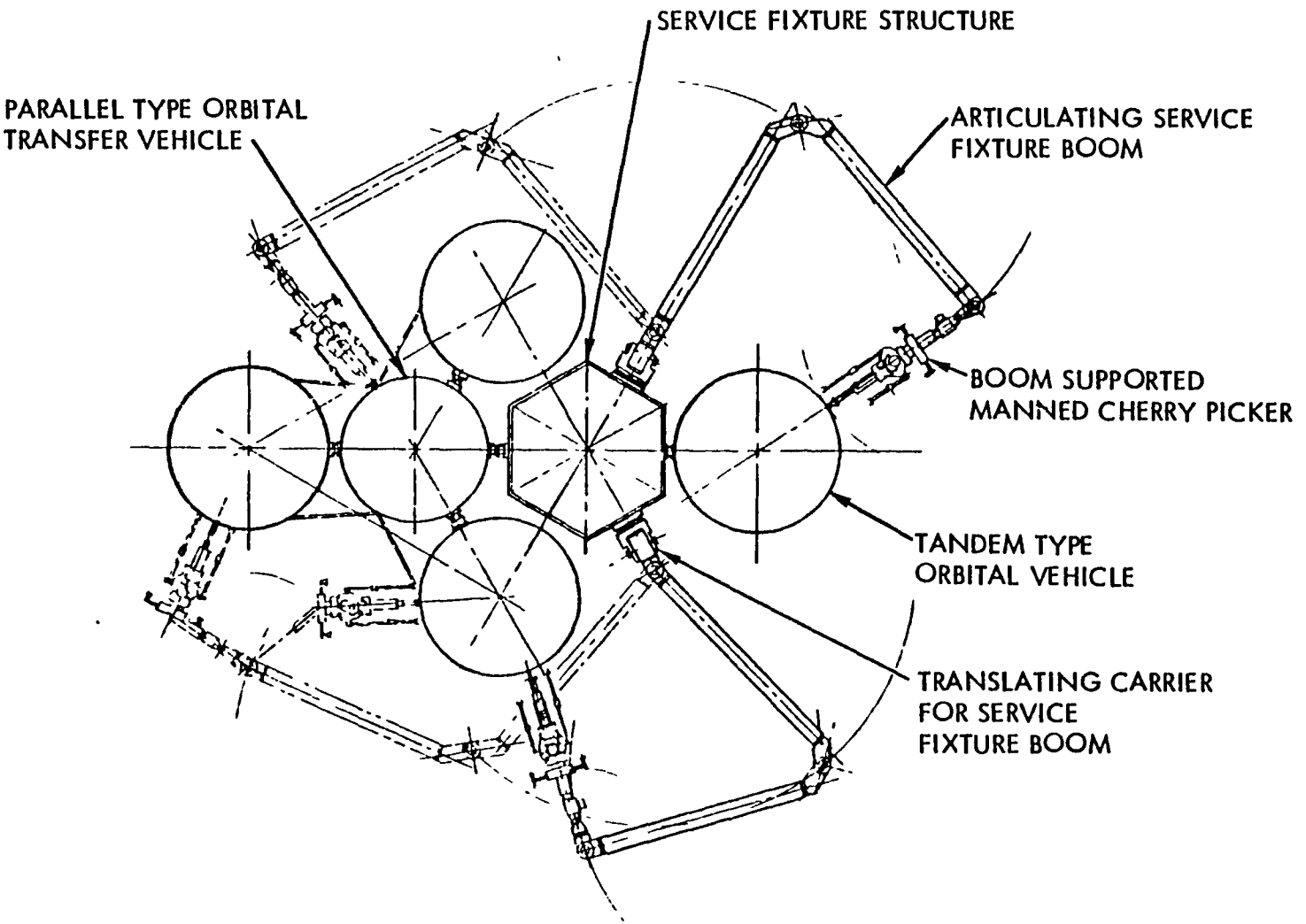
INITIAL FLIGHT SUPPORT FACILITY CONFIGURATION



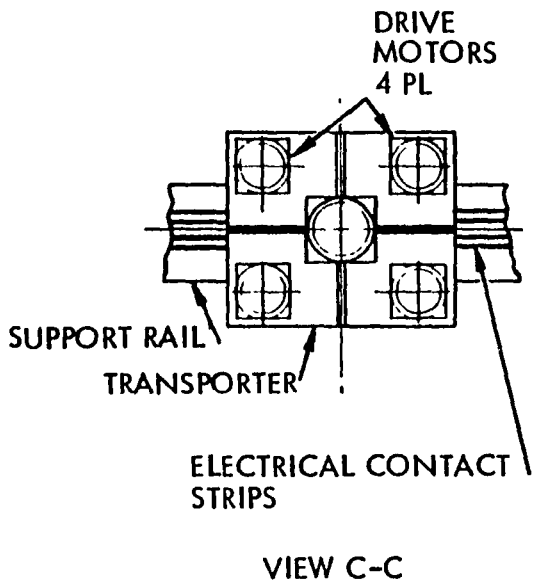
SERVICE FIXTURE ARRANGEMENTS



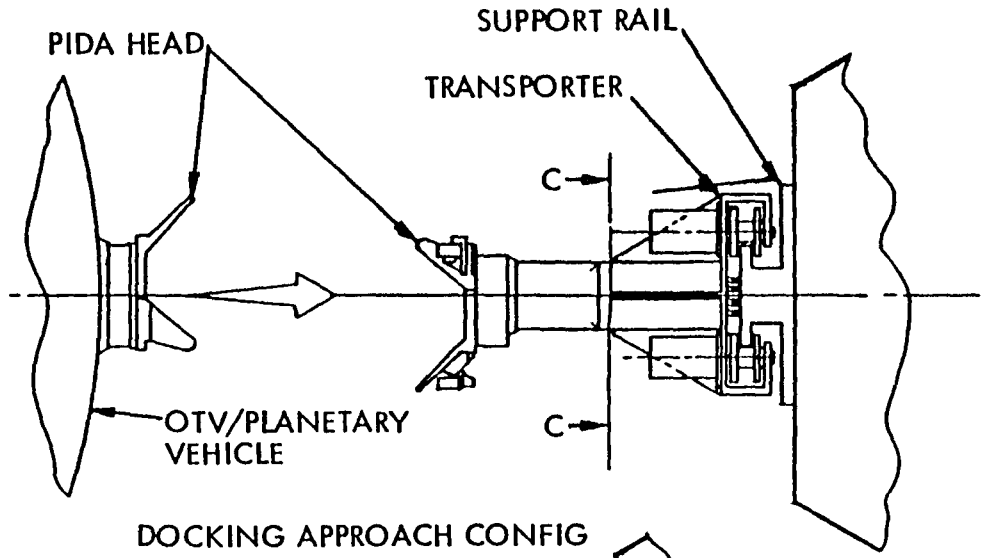
SF TRANSLATION RAIL SYSTEM AND HANDLING BOOM REACH CAPABILITY



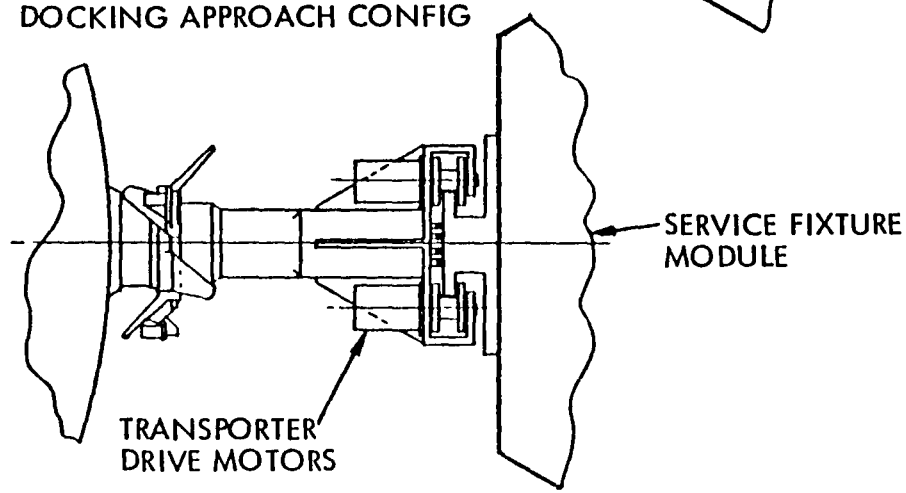
TRANSLATION RAIL SYSTEM WITH PIDA SUPPORTS



VIEW C-C

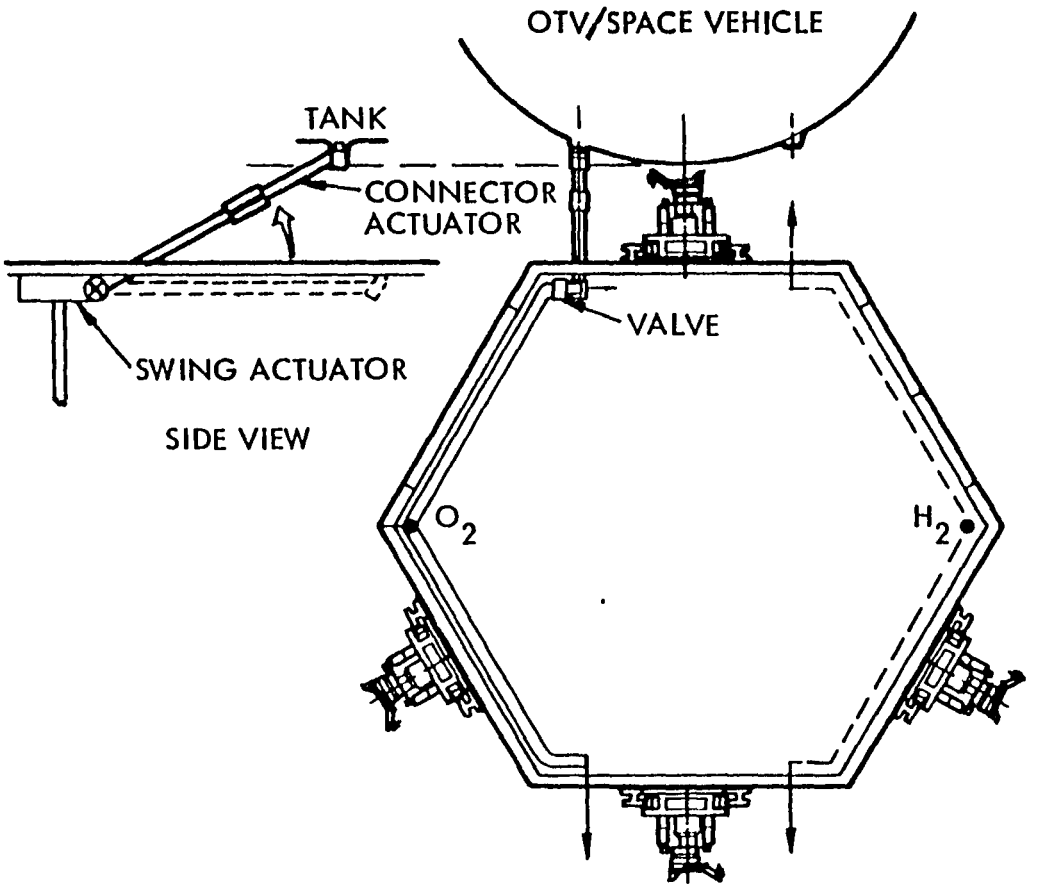


DOCKING APPROACH CONFIG

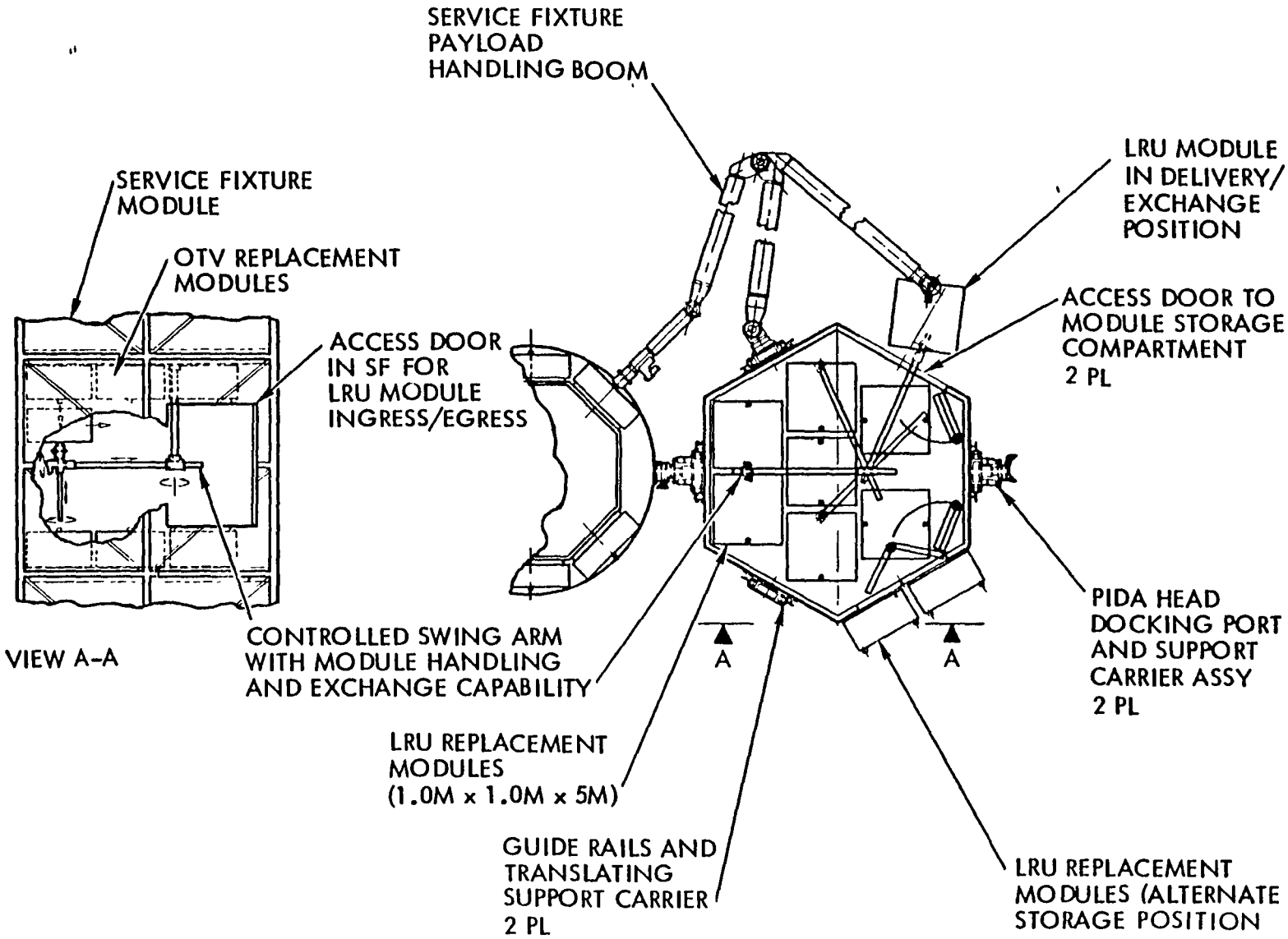


DOCKED CONFIG

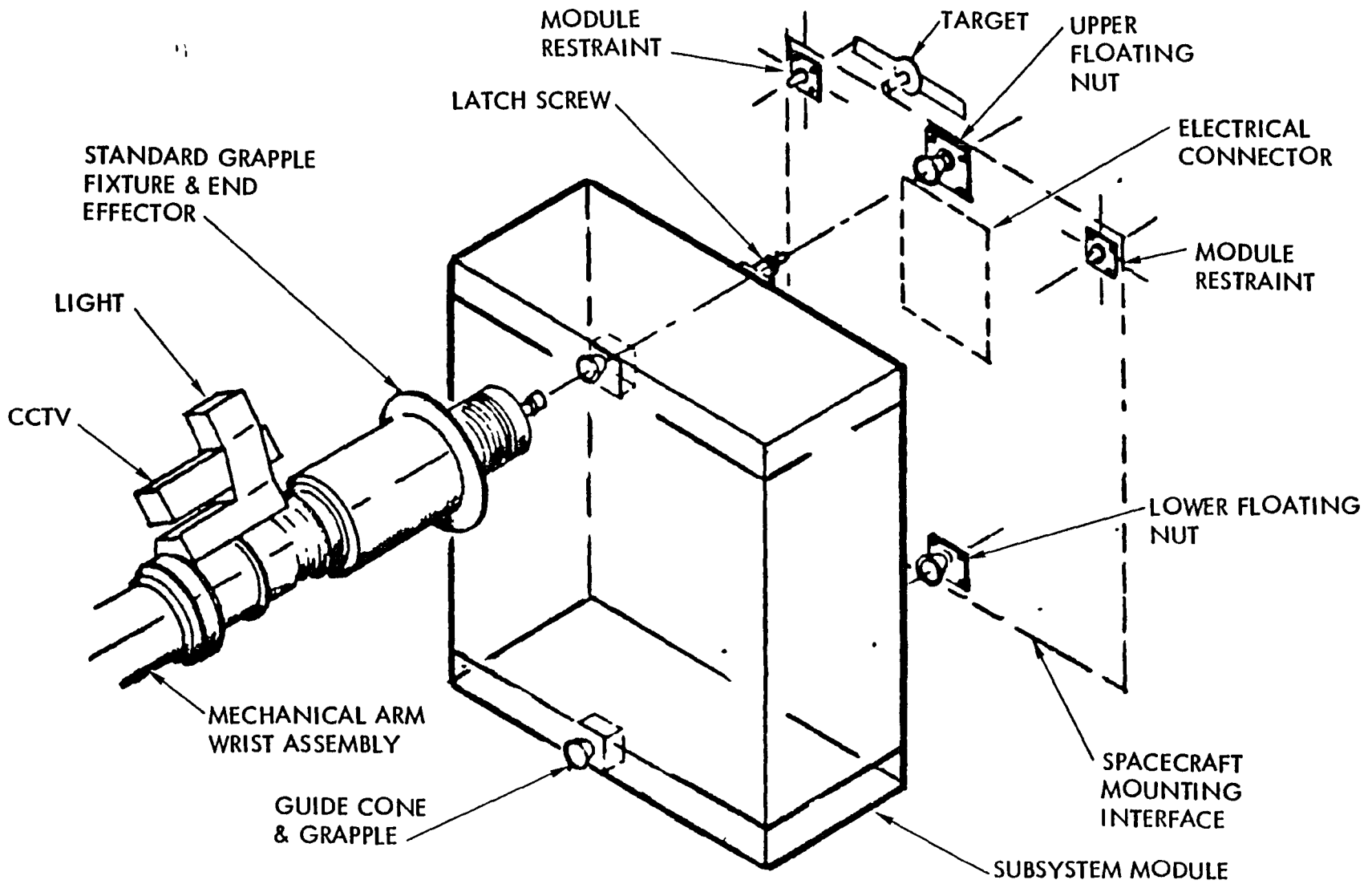
OTV REFUELING CONCEPT



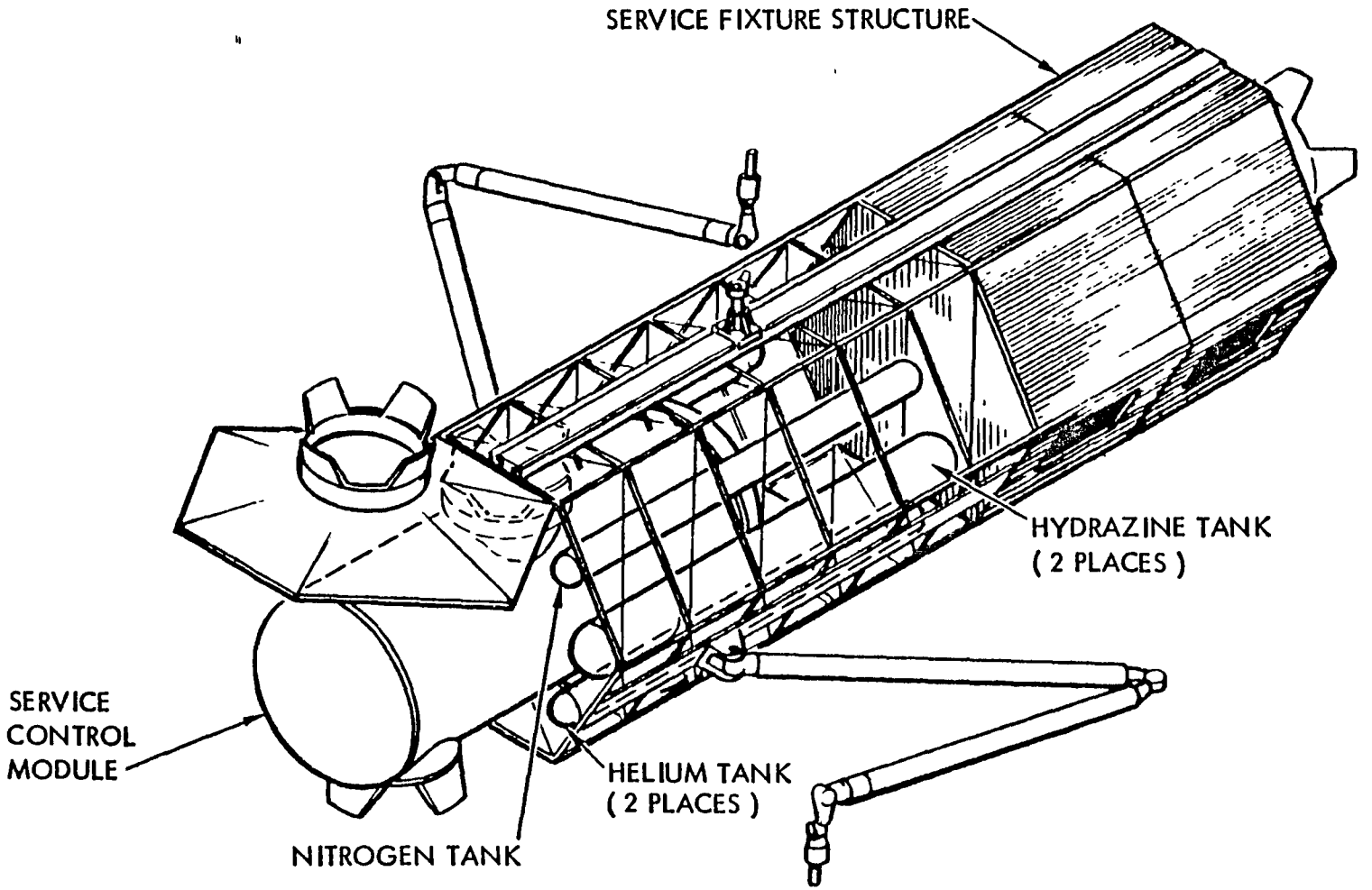
SF STOWAGE PROVISIONS



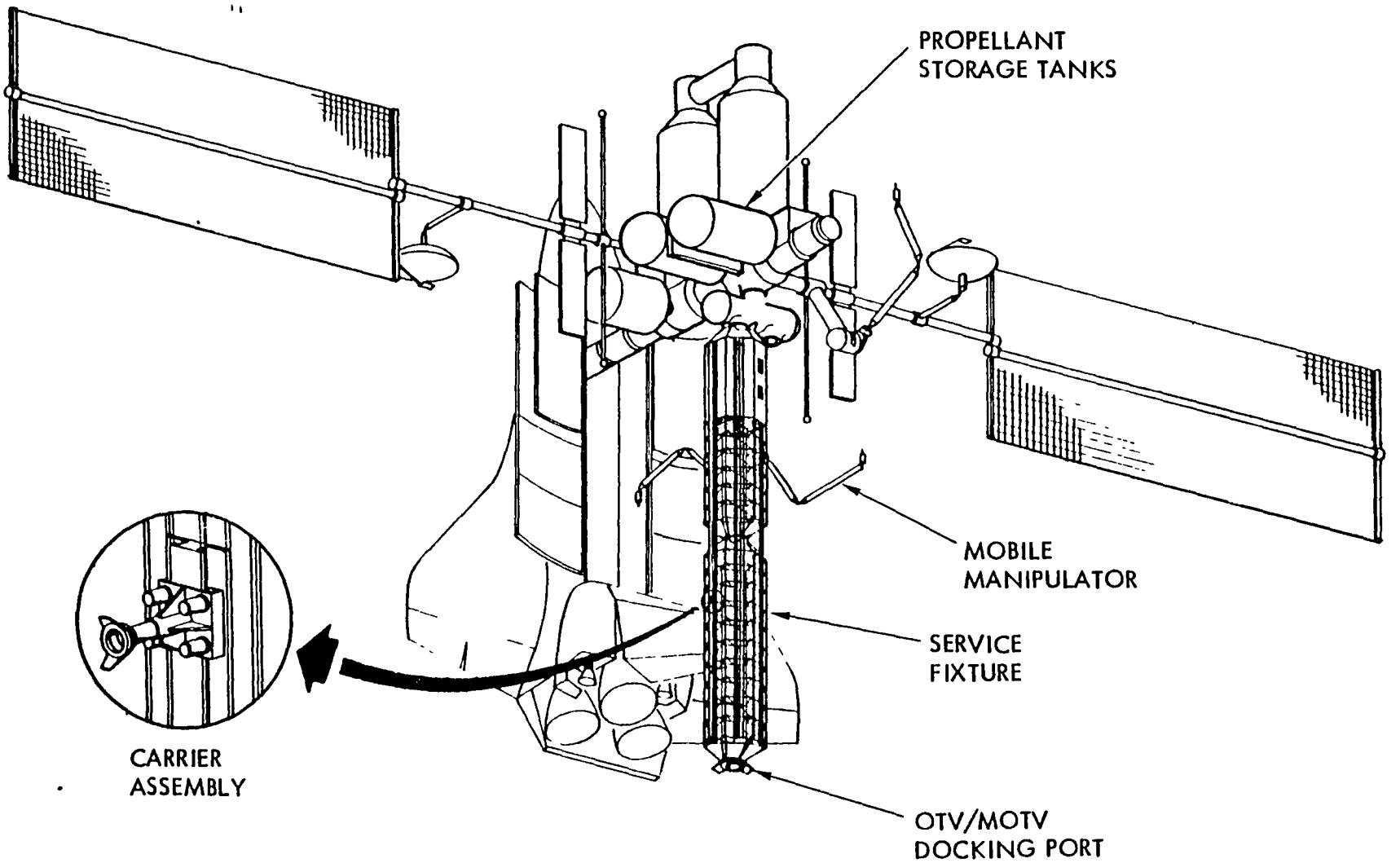
MULTI-MISSION SPACECRAFT SUBSYSTEM MODULE



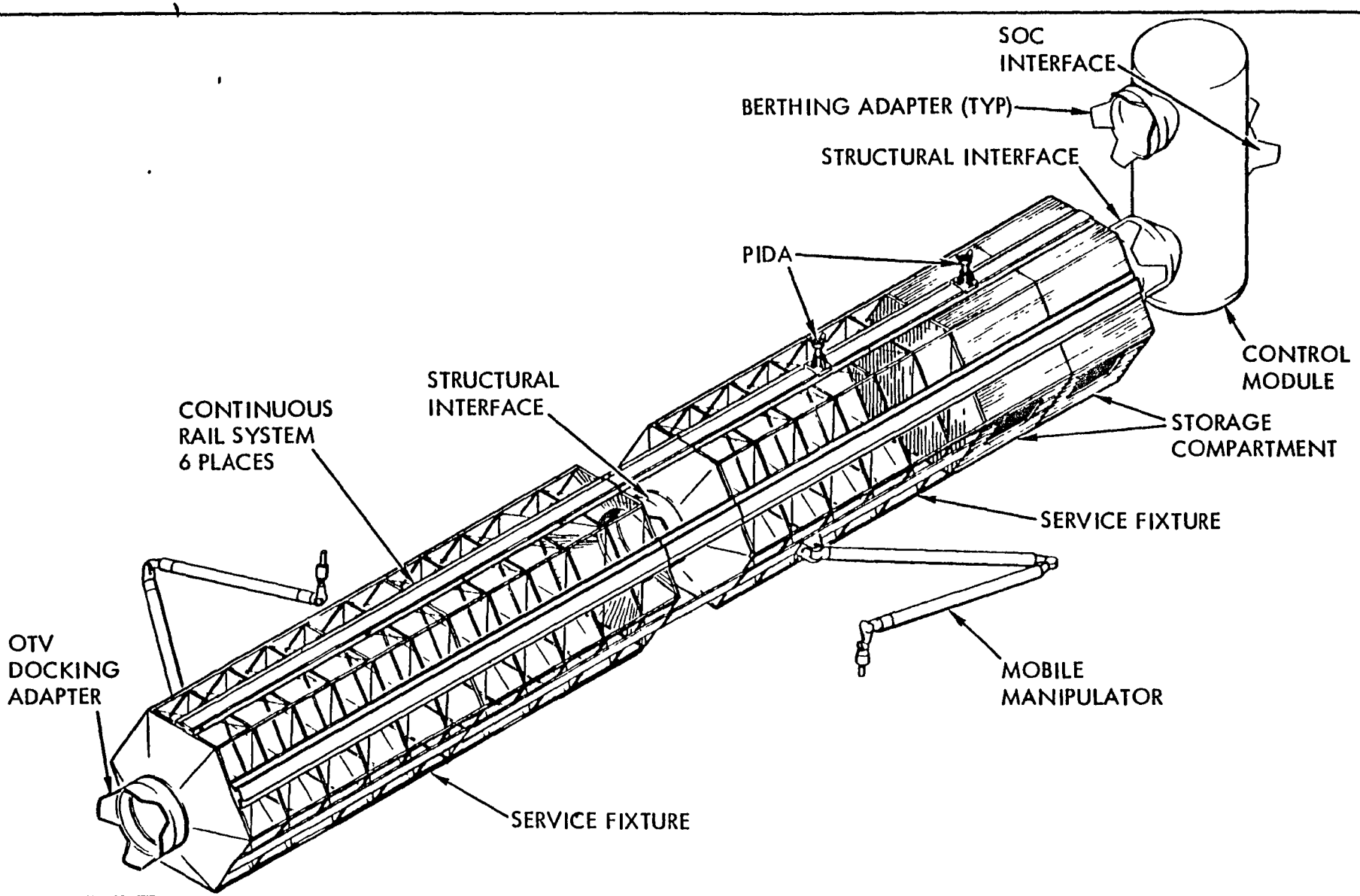
SF PACKAGING CONCEPT



FLIGHT SUPPORT FACILITY -- GROWTH CONFIGURATION

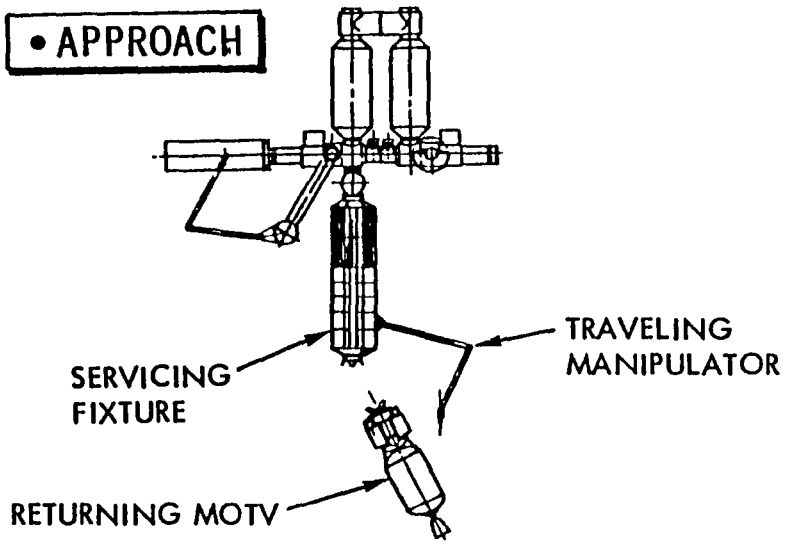


GROWTH PROVISIONS

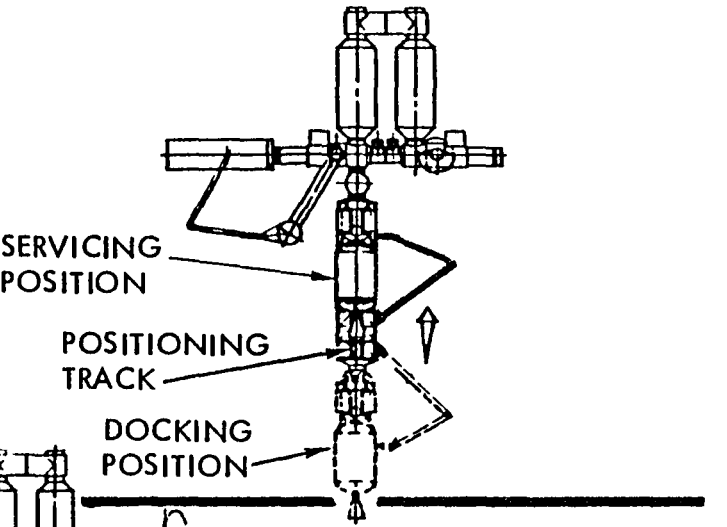


FLIGHT SUPPORT FACILITY OPERATION

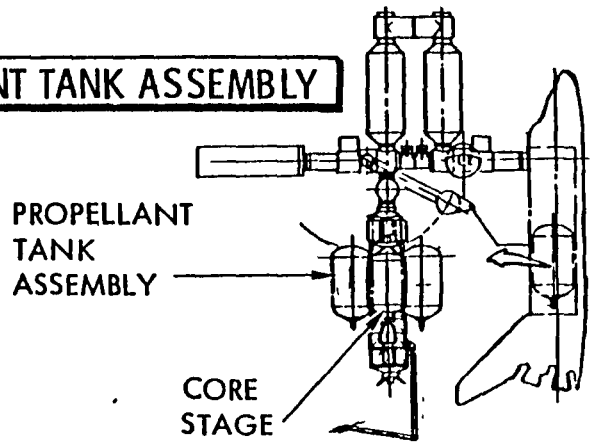
• APPROACH



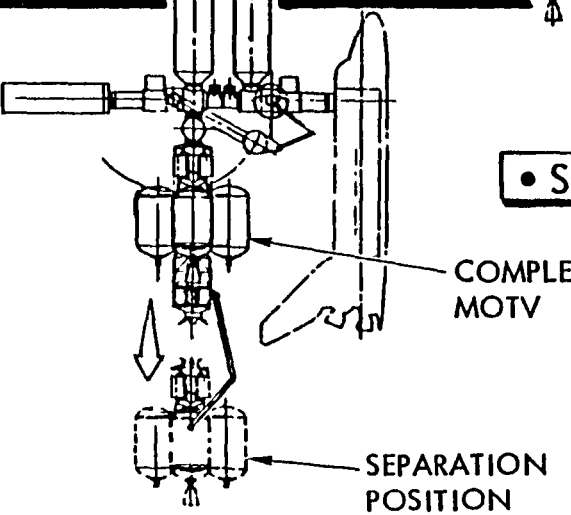
• DOCKING & POSITIONING FOR SERVICE



• PROPELLANT TANK ASSEMBLY



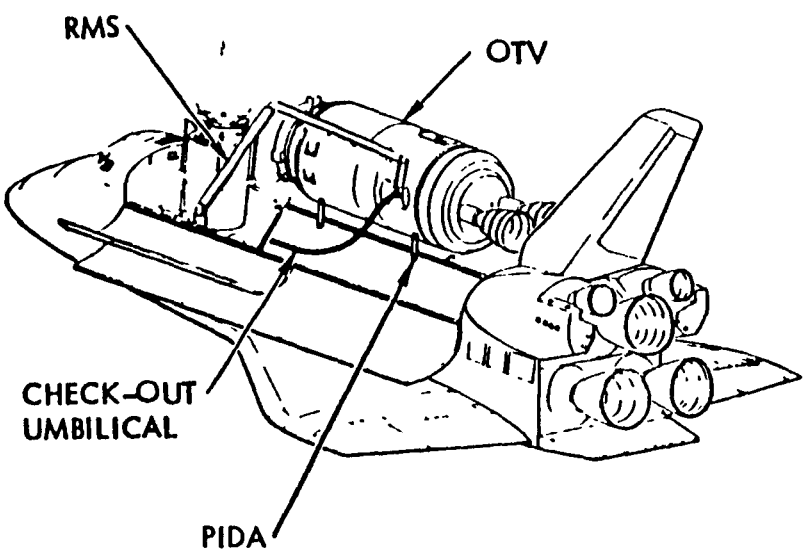
• SEPARATION

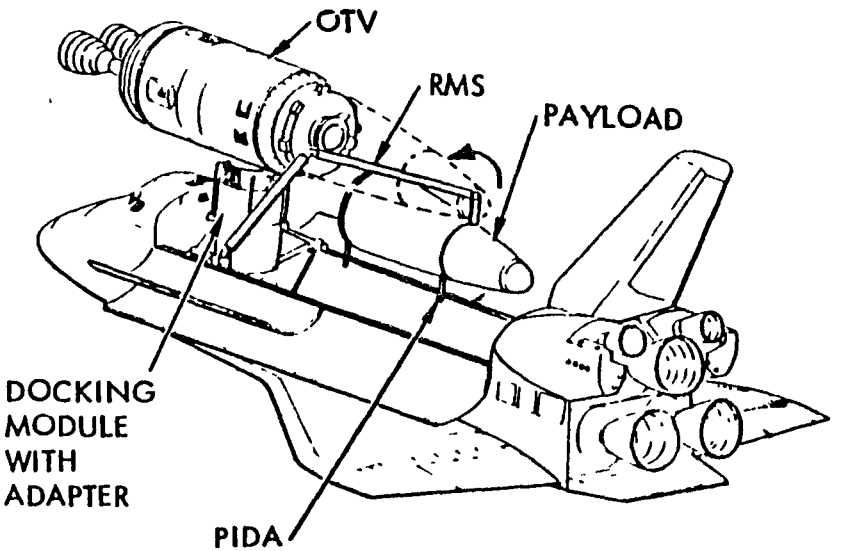


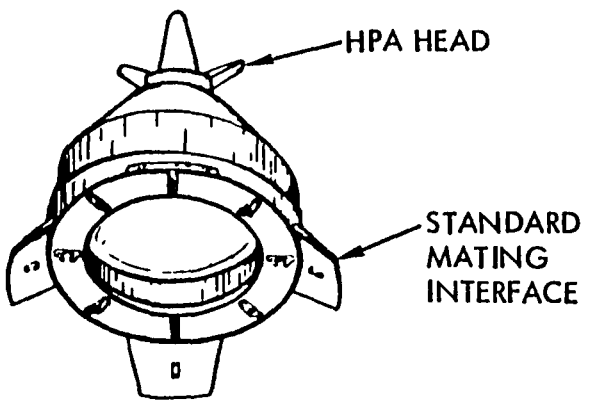
SPACE-BASED OTV SERVICING PROVISIONS

- STANDARD BERTHING PORT AT FORWARD END
- TWO PIDA ATTACH PROVISIONS ON BODY
- GRAPPLE FITTINGS TO ACCOMMODATE RMS
- EXTERNALLY MOUNTED SUBSYSTEM PACKAGES (LRU)
- ELECTRICAL UMBILICAL INTERFACE
- PROPELLANT FILL INTERFACE

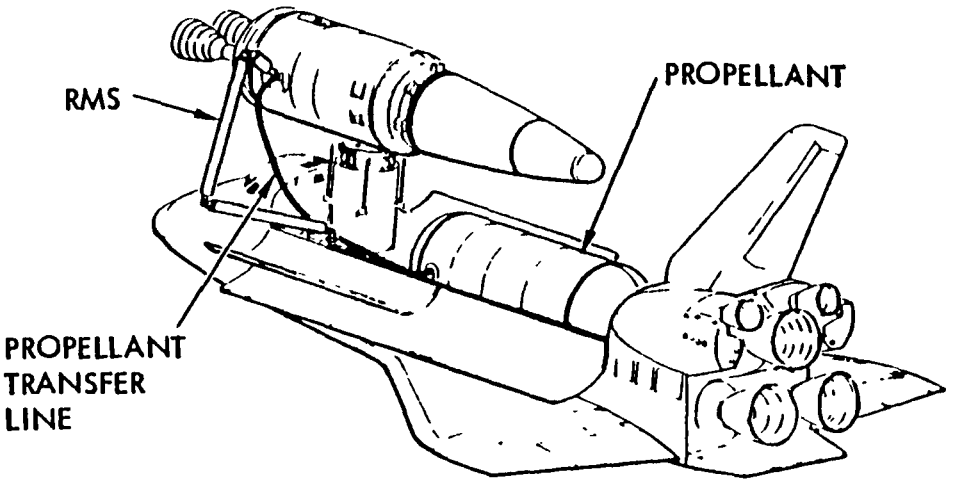
OTV/MOTV IN ORBIT ASSEMBLY FROM ORBITER







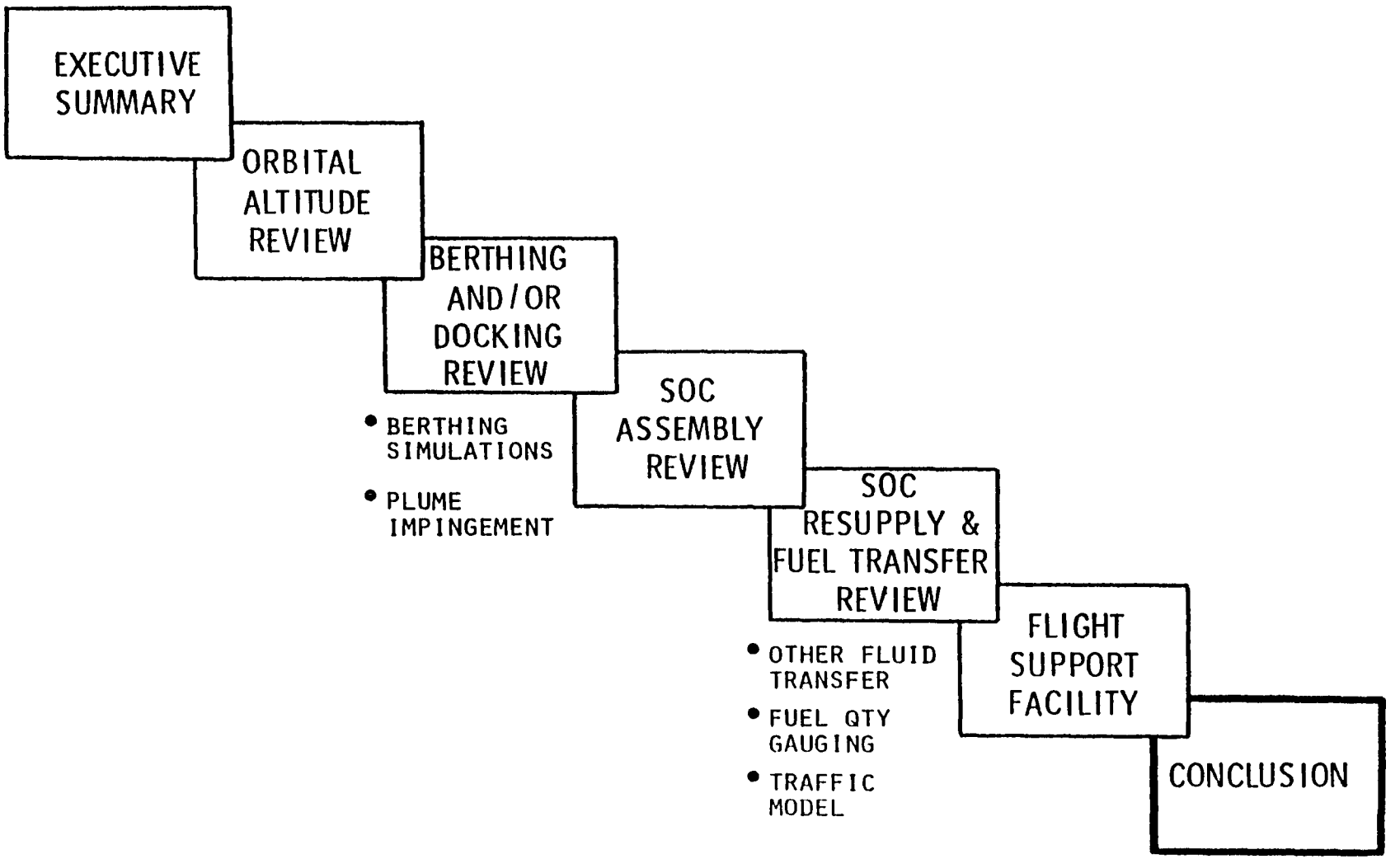
ADAPTER



TASK 5 CONCLUSIONS

- SERVICING PHILOSOPHY BASED ON AIRLINE OPERATIONS IS FEASIBLE
- IMPACT OF SPACECRAFT SERVICING CAPABILITY ON SOC IS A FLIGHT SUPPORT FACILITY THAT
  - PERFORMS MAJOR ASSEMBLY, MAINTENANCE, AND SERVICING OPERATIONS
  - INCLUDES A DEDICATED CONTROL CENTER (BACK-UP SOC CONTROL)
  - SERVICES MORE THAN ONE SPACECRAFT SIMULTANEOUSLY
  - PROVIDES FOR GROWTH CAPABILITY
- SPACECRAFT PROVISIONS TO PERMIT IN-SPACE SERVICING ARE NOMINAL AND FEASIBLE
- SHUTTLE PROVISIONS TO PERMIT IN-SPACE SERVICING ARE MINIMAL

AGENDA


EXECUTIVE SUMMARY
ORBITAL ALTITUDE REVIEW
BERTHING AND/OR DOCKING REVIEW
• BERTHING SIMULATIONS
• PLUME IMPINGEMENT
SOC ASSEMBLY REVIEW
SOC RESUPPLY & FUEL TRANSFER REVIEW
• OTHER FLUID TRANSFER
• FUEL QTY GAUGING
• TRAFFIC MODEL
FLIGHT SUPPORT FACILITY
CONCLUSION

CONCLUSION

- COMPLETED ANALYSIS OF THE FIVE TASKS
- IDENTIFIED A VARIABLE ALTITUDE STRATEGY FOR SOC OPERATIONS
- IDENTIFIED THE OPERATIONS NECESSARY TO DOCK OR TO BERTH SHUTTLE TO SOC
- DETERMINED PRELIMINARY REQUIREMENTS FOR A STANDARD MATING INTERFACE AND DOCKING MODULE
- IDENTIFIED EQUIPMENT REQUIRED FOR SOC BUILDUP IN ANY SEQUENCE
- IDENTIFIED PROPELLANT TRANSFER CONCEPTS AND PROPELLANT STORAGE BENEFITS
- IDENTIFIED A SPACECRAFT SERVICING CONCEPT
- DETERMINED A FLIGHT SUPPORT FACILITY CONCEPT FOR EARLY SOC OPERATIONS WITH GROWTH CAPABILITY
- IDENTIFIED IMPLICATIONS TO THE SOC, SHUTTLE, AND OTV

End of Document